JSC-10683
REV. A

PRELIMINARY FEASIBILITY STUDY OF
PALLET-ONLY MODE
FOR MAGNETOSPHERIC AND
PLASMAS IN SPACE
PAYLOADS
VOLUME 4

(NASA-TM-X-72909) PRELIMINARY FEASIBILITY STUDY OF PALLET-ONLY MODE FOR MAGNETOSPHERIC AND PLASMAS IN SPACE PAYLOADS, VOLUME 4 (NASA) 321 p HC $9.75 CSCL 22A

N76-28261

Unclas
G3/16 45829

National Aeronautics and Space Administration
LYNDON B. JOHNSON SPACE CENTER
Houston, Texas
June 1976

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1.0 INTRODUCTION

Volume IV is an addendum to the document entitled "Atmospheric Science Facility Pallet - Only Mode Space Transportation Systems Interim Report," (JSC-10683 - Revision A), dated November 1975. The basic interim report documented a study into the feasibility of accomplishing the scientific objectives of the Atmospheric Science Facility portion of the AMPS (Atmospheric, Magnetospheric, and Plasmas in Space) program using a pallet-only mode of payload packaging the command and operations equipment. Volume IV contains the results of studies performed on the magnetospheric and plasma portion of the AMPS.

Magnetospheric and Plasma in Space experiments and instruments are described along with packaging (palletization) concepts. Since only preliminary studies have been made on the subsystems and support required for these instruments, subsystems and support requirements are not addressed in this addendum.

The described magnetospheric and plasma experiments were considered as separate entities. Instrumentation requirements and operations were formulated to provide sufficient data for unambiguous interpretation of results without relying upon other experiments of the series. Obviously all the experiments may not be approved because of budgetary limitations, so self-sufficiency was also a necessary consideration. Some of the proposed experiments require cooperation of ground installations, but the logistics of such cooperation were not considered. Where ground observations are specified, an assumption was made that large-scale additions or modifications to existing facilities were not required.

The proposed magnetospheric and plasma experiments are based on the scientific objectives which have originated in the AMPS Science Definition Working Groups. No strong effort was made to combine overlapping objectives or requirements. The instruments employed are based on an interpretation of the Instrument Functional Requirements Documents (IFRD's) issued by the Working Groups. The instrument configurations are based on the most recent information available and are subject to change. Reasonable precautions have been taken in packaging the instrument configurations to minimize electromagnetic interference, but final placement will require reevaluation when definitive measurements of EMI are available.

In the experiment descriptions, priorities have been assigned to the instruments. The numbers shown are defined as follows:

a. 1 - Critical to performance of the experiment

b. 2 - Instrument acquires useful backup data and is highly desirable, but is not necessary for a successful experiment

c. 3 - Data are applicable to the experiment. Instrument is useful, but not necessary.

Also included in this Volume IV are descriptions of additional Atmospheric Science Facility experiments that were not described in Volume I or II. These additional descriptions are included in Appendix A of this document.

In describing the Atmospheric Science Facility instrumentation in Volume I, II, III, and IV and the Magnetospheric and Plasmas in Space instrumentation in Volume IV, repeated references are made to the AMPS IFRD's (Instrument Functional Requirements Documents) which were generated by the AMPS Scientific Working Group between August 1974 to February 1976. Table 1-I lists the instruments identified, defined, or discussed in this report together with the related IFRD identification number. (Ref. Baseline AMPS Instrument Functional Requirements, February 1976). Instrument numbers which appear in the report were developed for use in the study as described in Volume I. The IFRD numbers were not developed and assigned to instruments until after completion of Volume I and II.

TABLE 1-I.- AMPS INSTRUMENTS/IDENTIFICATION

Report instrument number	Related IFRD number	Instrumentation identification
116	-	Airglow Spectrograph
118	II 7	Limb Scanning IR Radiometer
120	I 2	Meteor Gun
121	III 23	Neutral Mass Spectrometer
122	II 4	UV-VIS-NIR Spectrometer
123	II 5	Far UV TV System
124	II 6	Fabry-Perot Interferometer
125	-	Neutral Temperature & Wind Drift Spectrometer
126	II 10	Cryo-Cooled Interferometer Spectrometer
128	II 11	Atmospheric Bremsstrahlung Array
129	II 9	Near II Interferometer/Spectrometer
213	I 1	Laser Sounder
301	I 11	Ion Accelerator
303	I 8, 9	Electron Accelerator
304	I 5	Magnetoplasmadynamic (MPD) Arc
306	I 6	High Voltage Plasma Gun
405	I 12	Radio Frequency Sounder
406	I 13	Incoherent Scatter Radar
407	I 18, 19	ULF Antenna and Transmitter

TABLE 1-I.- AMPS INSTRUMENTS/IDENTIFICATION (Continued)

Report instrument number	Related IFRD number	Instrumentation identification
408	II 12	Tethered Satellite for ULF Magnetospheric Measurements
409	I 20	Doppler Tracking Bistatic Sounder for AMPS Wake
410	I 14	Coherent Scatter Radar
411	I 16	Extreme Low Frequency (ELF)/Very Low Frequency (VLF) Receiver.
415	I 16	VLF Quadrupole Probe for Lower Hybrid Modes.
416	I 16	Six Component Measurements of Random VLF Wave Fields
417	I 16	Resonance Cone
418	I 17	VLF Antennas and Transmitter
421	- -	Group Velocity Measurements
424	-	Microwave Limb Scanner
526	II 2	Photoelectron/Secondary Electron Spectrometer
527	III 22	Langmuir Probe
529	III 6, 20	Energetic Ion Mass Analyzer
530	I 16	High Frequency Quadrupole Probe
531	III 13, 24	Energetic Ion Mass Analyzer (Subsatellite)
532	I 3	Gas Release Module
533	I 4	Plasma Accelerator (TAPAC)

TABLE 1-I.- AMPS INSTRUMENTS/IDENTIFICATION (Continued)

Report instrument number	Related IFRD number	Instrumentation identification
534	II 3	Optical Band Imager and Photometer (OBIPS)
535	III 21	Dc Electrical Fields
536	III 2	Triaxial Fluxgate Magnetometer
537	III 10	Ion Mass and Distribution Analyzer
538	III 16	Ion Mass and Distribution Analyzer (Subsatellite)
540	III 12, 15	Medium Energy Ion Mass Analyzer
541	III 6	Energetic Ion Detector
542	III 9, 15	Medium Energy Ion Detector
543	III 11, 14	Energetic Electron Detector
544	III 7, 8	Medium Energy Electron Detector
546	I 7	Plasma Accelerator (SEPAC)
547	III 1	Ion Drift Detector
548	III 2	Vector Magnetometer
549	III 3	Level I Diagnostics Gas Plume Release
550	III 4	Level II Beam Diagnostics
551	III 5	Level III Beam Diagnostics (B, E, and fast V_P Probes)
552	I 10	Low Energy Electron Beam Experiments (Leebex)
553	-	Electromotive Force Generator

TABLE 1-I.- AMPS INSTRUMENTS/IDENTIFICATION (Concluded)

Report instrument number	Related IFRD number	Instrumentation identification
554	I 21	Chemical Release Module
555	III 21	Diagnostic Package For EMI (ESP)
556	III 17	Target Bodies
557	-	Booster Firing
1002/1003		Pyroheliometer Spectrophotometer
1007		Eschell Spectrograph
1009		XUV-UV Solar Intensity Monitor
1011	II 1	UV Occultation Spectrograph

2.0 INSTRUMENT PACKAGING APPROACH

The packaging of instruments was approached from the prototype experiments proposed for the AMPS missions using the science objectives documents generated by the Scientific Working Group. The experiments were examined in detail to determine how to perform them and which of the proposed instruments would be applicable to each of the experiments.

A matrix of the required experiments vs. instruments was developed (Table 2-I). Experiments in the matrix were grouped loosely by scientific discipline while the instruments were grouped on pallets by function, i.e., particle detectors, particle accelerators, RF, or optical. There was some interaction of discipline between experiments because of the nature of the experiments. The same was true of instrument functions. When entering instruments into the matrix, a priority system was employed. First priority was given to instruments that are critical to an experiment, second priority to those that acquire useful backup data, and third priority to those taking data that might be applied to the experiment results, but are not necessary to fulfill the experiment requirements.

The first attempt to choose packages was accomplished by trying to tailor instrument packages to experiments and work toward a common configuration. Using this method proved to be too inflexible and the decision was made to use the facility concept. Using this concept, a number of pallet packages were developed in which instruments were grouped by: (a) function; (b) use; and (c) number of times a specific group of instruments would be used in conjunction with another group. The criteria were not firm, but they were used as guidelines to group instruments for a pallet. This "facility" concept proved workable.

The next step was to tabulate the required instruments by size, weight, field of view, pointing requirements, and any unique operating problems such as long antennas, or boom mounting because of EMI or contamination.

Using the functional requirements, various configurations were developed. In some cases, instruments were moved from the originally proposed position because of physical, electrical, or field-of-view interference. A series of eight pallets evolved that would satisfy the AMPS Program with the exception of a few specialized experiments. Included in the latter category are: (a) large chemical releases; (b) high-powered radar requiring a large parabolic antenna; (c) tethered satellites or balloons; and (d) other undefined instruments referred to in experiments which are expected to be large.

The four pallets of instruments needed for atmospheric experiments have been described in the Interim ASF Report and will not be repeated in this memorandum.

The four basic pallets required for the magnetospheric and plasma experiments are the Optical/Particle pallet, the Accelerators pallet, the Radio Frequency pallet, and the Subsatellite Carrier pallet. Table 2-II lists the experiments included on each pallet. Table 2-III lists the instruments on each pallet.

TABLE 21· MATRIX OF EXPE

MAGNETOSPHERICS AND PLASMAS	116 Airglow Spectrograph	118 Limb Scanning IR Radiometer	122 UV/VIS/NIR Spectrometer	124 Fabry-Perot Interferometer	126 Far IR Spectrometer	129 Near IR Interf./Spect.	1011 UV Occultation Spectrograph	1002 Pyrheliometer/Spectrometer	424 Microwave Limb Scanner	213 LIDAR	534 OBIPS
3.12 Modification of the Magnetospheric Bulk Flow	3										1
3.19 Generation of Upper Atmosphere Gravity Waves			3								1
4.10 Plasma-Neutral Gas Interactions	3		2								1
3.18 Creation of Plasmasphere Density Ducts											
3.14 Trace Polar Wind and Transport											1
3.17 Magnetic Field Configuration Studies											1
3.13 Cold Plasma Injection											1
3.16 Trace Magnetospheric Particle Access and Motion											1
4.11 Creation of an Artificial Comet	3		2	3		3					1
3.6 Measurement of Field Aligned (Birkeland) Currents	3		2								1
3.10 Hydromagnetic Wave Measurements											
3.15 Electric Field Measurements Using Multiprobes											
4.12 Plasma Flow Interactions with Target Bodies											
4.2 Plasma EMF Experiment											
3.1 Auroral Input – Output Experiment			2								1
4.1 Interaction of Electron and Ion Beams with Plasma			3								2
3.2 Electron Beam Echo Measurements of $E_\parallel$ and Mag											1
3.4 Measurements of Parallel Electric Fields			2								1
3.5 Modification of Ionospheric Conductivity											1
3.3 Modification of Ionospheric Parameters			2								1
3.9 6-Component Measurements of Random ELF and											
3.11 ULF Antenna Measurements											
4.3 ELF-VLF Antenna Measurements											
4.4 Resonance Cone Techniques											
4.5 High Frequency Electrostatic Wave Experiments											
4.8 Lower Hybrid Resonance Experiments											
4.13 Sounding of the Shuttle Wake											
3.7 VLF/ELF Wave Injection Experiments											1
4.9 Pulse Propagation and Group Delay											
4.7 Radio Frequency Sounder											
3.8 Ionospheric Heating and Coherent Scatter Measurement											3
4.6 Long Delayed Echoes											
APPENDIX A ASF											
1.1 Budget and Chemistry in Ozone		X		X	X	X		X	X	X	
1.2 Chemical and Diffusive Equilibrium	X		X	X				X	X	X	
1.3 Absolute Density and Variability of Atomic Oxygen			X	X					X	X	
1.4 D-Region Changes at Middle Latitudes During Winter			X	X	X	X				X	X
1.5 Meteoric Material and Its Interaction	X	X	X	X	X	X				X	X
1.6 Vibrationally Excited OH (and Its Effects Upon Atm)		X		X		X	X			X	
2.1 Temperature Profile from 50 to 120 Km.		X		X	X	X			X	X	
2.2 Eddy Diffusion Coefficients from the Distribution		X		X	X		X		X	X	
2.3 Horizontal Winds in the Mesosphere and Thermosphere				X						X	
2.4 Relative Importance of Particle and Joule Heating	X		X	X						X	
2.5 Atmospheric tides and Gravity Waves		X	X	X	X	X	X	X		X	X
2.6 Ionospheric Current Systems		X		X	X	X				X	X
2.7 Physical Processes in the Auroral Atmosphere	X		X	X							X
3.1 Correlation Between Particle Precipitation and Ozone		X			X	X			X	X	
3.2 Anomalous Neutral Composition Near Aurora	X		X	X	X	X			X	X	X
3.3 The Influence of Solar Magnetosphere Variations Upon	X	X	X	X	X	X	X		X	X	X
4.1 Basic Atomic and Molecular Processes	X		X	X		X				X	X
	116	118	122	124	126	129	1011	1002	424	213	534

MAGNETOSPHERICS AND PLASMAS	301 Ion Accelerator	303 Electron Accelerator	304 MPD Arc	306 H.V. Plasma Gun	549 Level I Diagnostic	550 Level II Beam Diagnostic	551 Level III Diagnostic	552 LEEBEX	546 SEPAC
3.12 Modification of the Magnetospheric Bulk Flow									
3.19 Generation of Upper Atmosphere Gravity Waves									
4.10 Plasma-Neutral Gas Interactions									
3.18 Creation of Plasmasphere Density Ducts									
3.14 Trace Polar Wind and Transport									
3.17 Magnetic Field Configuration Studies									
3.13 Cold Plasma Injection									
3.16 Trace Magnetospheric Particle Access and Motion									
4.11 Creation of an Artificial Comet									
3.6 Measurement of Field Aligned (Birkeland) Currents									
3.10 Hydromagnetic Wave Measurements									
3.15 Electric Field Measurements Using Multiprobes									
4.12 Plasma Flow Interactions with Target Bodies									
4.2 Plasma EMF Experiment	1	1			2	1			
3.1 Auroral Input – Output Experiment	2	1			1	1			
4.1 Interaction of Electron and Ion Beams with Plasma	1	1			1	2	3	2	
3.2 Electron Beam Echo Measurements of $E_\parallel$ and Mag		1			1	1			
3.4 Measurements of Parallel Electric Fields	1	1			1	1			
3.5 Modification of Ionospheric Conductivity		1			1	1			
3.3 Modification of Ionospheric Parameters			1	2					2
3.9 6-Component Measurements of Random ELF and									
3.11 ULF Antenna Measurements									
4.3 ELF-VLF Antenna Measurements	1	1			1	1			
4.4 Resonance Cone Techniques									
4.5 High Frequency Electrostatic Wave Experiments									
4.8 Lower Hybrid Resonance Experiments									
4.13 Sounding of the Shuttle Wake									
3.7 VLF/ELF Wave Injection Experiments	1	2			1	2			
4.9 Pulse Propagation and Group Delay									
4.7 Radio Frequency Sounder									
3.8 Ionospheric Heating and Coherent Scatter Measurement									
4.6 Long Delayed Echoes									
APPENDIX A ASF									
1.1 Budget and Chemistry in Ozone									
1.2 Chemical and Diffusive Equilibrium									
1.3 Absolute Density and Variability of Atomic Oxygen									
1.4 D-Region Changes at Middle Latitudes During Winter									
1.5 Meteoric Material and Its Interaction									
1.6 Vibrationally Excited OH (and Its Effects Upon Atm)									
2.1 Temperature Profile from 50 to 120 Km.									
2.2 Eddy Diffusion Coefficients from the Distribution									
2.3 Horizontal Winds in the Mesosphere and Thermosphere									
2.4 Relative Importance of Particle and Joule Heating									
2.5 Atmospheric tides and Gravity Waves									
2.6 Ionospheric Current Systems									
2.7 Physical Processes in the Auroral Atmosphere									
3.1 Correlation Between Particle Precipitation and Ozone									
3.2 Anomalous Neutral Composition Near Aurora									
3.3 The Influence of Solar Magnetosphere Variations Upon									
4.1 Basic Atomic and Molecular Processes		X	X		X	X			
	301	303	304	306	549	550	551	552	546

MAGNETOSPHERICS AND PLASMAS	405 R. F. Sounder	407 ULF Antenna and Transmitter	408 Tethered Satellite	409 Bistatic Sounder	410 Coherent Scatter Radar	411/416 ELF/VLF Receiver	530 H. F. Quadrupole Probe	415 VLF Quadrupole Probe	417 Resonance Cone	418 VLF Antennas and Transmitters	421 Group Velocity Meas.
3.12 Modification of the Magnetospheric Bulk Flow											
3.19 Generation of Upper Atmosphere Gravity Waves											
4.10 Plasma-Neutral Gas Interactions	2					2					
3.18 Creation of Plasmasphere Density Ducts	1									2	
3.14 Trace Polar Wind and Transport	1					2					
3.17 Magnetic Field Configuration Studies											
3.13 Cold Plasma Injection	1					1					
3.16 Trace Magnetospheric Particle Access and Motion						2					
4.11 Creation of an Artificial Comet											
3.6 Measurement of Field Aligned (Birkeland) Currents	2					2					
3.10 Hydromagnetic Wave Measurements											
3.15 Electric Field Measurements Using Multiprobes											
4.12 Plasma Flow Interactions with Target Bodies						2	2				
4.2 Plasma EMF Experiment											
3.1 Auroral Input – Output Experiment											
4.1 Interaction of Electron and Ion Beams with Plasma											
3.2 Electron Beam Echo Measurements of $E_\parallel$ and Mag											
3.4 Measurements of Parallel Electric Fields											
3.5 Modification of Ionospheric Conductivity											
3.3 Modification of Ionospheric Parameters											
3.9 6-Component Measurements of Random ELF and						1					
3.11 ULF Antenna Measurements		1	1								
4.3 ELF-VLF Antenna Measurements	1										
4.4 Resonance Cone Techniques									1		
4.5 High Frequency Electrostatic Wave Experiments											1
4.8 Lower Hybrid Resonance Experiments								1			
4.13 Sounding of the Shuttle Wake				1							
3.7 VLF/ELF Wave Injection Experiments										1	
4.9 Pulse Propagation and Group Delay											1
4.7 Radio Frequency Sounder	1					2		3		2	
3.8 Ionospheric Heating and Coherent Scatter Measurement	1				1						
4.6 Long Delayed Echoes	1										
APPENDIX A ASF											
1.1 Budget and Chemistry in Ozone											
1.2 Chemical and Diffusive Equilibrium											
1.3 Absolute Density and Variability of Atomic Oxygen											
1.4 D-Region Changes at Middle Latitudes During Winter			X								
1.5 Meteoric Material and Its Interaction											
1.6 Vibrationally Excited OH (and Its Effects Upon Atm)											
2.1 Temperature Profile from 50 to 120 Km.											
2.2 Eddy Diffusion Coefficients from the Distribution											
2.3 Horizontal Winds in the Mesosphere and Thermosphere			X								
2.4 Relative Importance of Particle and Joule Heating											
2.5 Atmospheric tides and Gravity Waves											
2.6 Ionospheric Current Systems											
2.7 Physical Processes in the Auroral Atmosphere											
3.1 Correlation Between Particle Precipitation and Ozone											
3.2 Anomalous Neutral Composition Near Aurora											
3.3 The Influence of Solar Magnetosphere Variations Upon											
4.1 Basic Atomic and Molecular Processes											
	405	407	408	409	410	411/416	530	415	417	418	421

LE 21. MATRIX OF EXPERIMENTS VS. INSTRUMENTS

405 R. F. Sounder	407 ULF Antenna and Transmitter	408 Tethered Satellite	409 Bistatic Sounder	410 Coherent Scatter Radar	411/416 ELF/VLF Receiver	530 H. F. Quadrupole Probe	415 VLF Quadrupole Probe	417 Resonance Cone	418 VLF Antennas and Transmitters	421 Group Velocity Meas.	532 Gas Release Module	554 Chemical Release Module	557 Booster Firing	553 EMF Generator	556 Target Bodies	535 D.C. Electric Field	548 Vector Magnetometer	526 Photoelectron Spectrometer	527 Langmuir Probe	529 Energetic Ion Mass Analyzer	537 Ion Mass and Distribution	540 Medium Energy Ion Analyzer	541 Energetic Ion Detector	542 Medium Energy Ion Detector	543 Energetic Electron Detector	544 Medium Energy Electron	547 Ion Drift Detector	121 Neutral Mass Spectrometer	PDSS, ASF	RFSS with 548, 411, 555	TAM, 548	EFP, 555, 548	Solar Satellite	PDSS, M&P	121 Neutral Mass Spectrometer	125 Neutral Temperature	526 Photoelectron Spectrometer	527 Langmuir Probe	531 Energetic Ion Mass	535 D.C. Electric Field	538 Ion Mass and Distribution	540 Medium Energy Ion Analyzer	541 Energetic Ion Detector	542 Medium Energy Ion Detector	543 Energetic Electron Detector	544 Medium Energy Electron	548 Vector Magnetometer	Orbit*		
												1	1				1		3	3	2	2	3	2	3	1								1	1	2	1	2	2	2	1	1	2	2	2	1	1	P		3.12
												1	1																				1	1	1	1	2	3	2	1	2	3	2	3	2	1	P		3.19
2					2							1					1															1		1	2		2	2			1						1	P		4.10
1									2			1																		1				1														L	No. 405 on RFSS	3.18
1					2							1	1				1		3	3	2	2	3	2	3	2				1				1	1	1	2	3	3	2	2	2	3	3	3	2	1	P	No. 405 on RFSS	3.14
												1	1				1	3	3	3	2	3	3	3	3	3								1	2	3	3	3	3	3	2	3	3	3	3	3	1	P		3.17
1					1							1	1				1		3	3	1	3	2	1	2	2				1																		L	No. 415 on RFSS	3.13
					2							1	1			2	2	3	3	1	3	1	3	3	3	3								1	3	3	2	3	1	2	1	2	2	2	2	2	1	P	SS in tail at R=8-10?	3.16
												1	1																				1	2	2	2	3	2	1	1	2	3	2	2	22	1		Same	4.11
2					2											1	3	3		2		3	2	2	2					1																		P	3 TAM's at least	3.6
																														1																		P&L	1 TAM at least	3.10
																1															1																	P	3 to 6 EFP's	3.15
					2	2									1	1	1	1	1		1							1						1			1	1			1						1	L	Maneuverable PDSS?	4.12
														1			1	1	1		2		3	2	3	2				1																		A	Low priority	4.2
																1																	1			2	1				2			2	1	1	P		3.1
																1																															L	L preferred	4.1
																1	2		3	2	3	3	3	3	1								1	3	3	1	1	3	1	2	3	3	2	2	1		P&L		3.2
																1			3	1	2	3	2	3	1								1														P	P preferred	3.4
																1																															P		3.5
																1													1				1			1	2		1	1				3	1	1	P	546 is substitute for 304, 306	3.3
					1											1													1																		P	P preferred	3.9
	1	1														1													1																		P		3.11
1																													1																		A		4.3
								1								1				2																											A		4.4
										1						1		2		2																											L		4.5
							1									1				1																											L	L preferred	4.8
			1												3		1	2	3																												A	Desire maneuverable RFSS	4.13
									1							1	2		3		3	3	3	3	2				1																		P		3.7
										1						1		2		2									1																		P	Questionable feasibility	4.9
1					2		3		2							1													1																		A		4.7
1				1														3		2																											A		3.8
1																									1								1												2		A		4.6
										X																																							1.1
																												X				X																		1.2
																																X																		1.3
		X																										X																						1.4
																																																		1.5
																																																		1.6
																																X																		2.1
																																																		2.2
		X																										X																						2.3
															X													X				X																		2.4
																X												X				X																		2.5
															X	X												X			X	X																		2.6
															X													X				X																		2.7
																												X				X																		3.1
															X	X												X				X																		3.2
															X	X																X																		3.3
											X						X											X					X																		4.1
405	407	408	409	410	411/416	530	415	417	418	421	532	554	557	553	556	535	548	526	527	529	537	540	541	542	543	544	547	121	PDSS	RFSS with 548, 411, 555	TAM, 548	EFP, 555, 548	Solar Satellite		121	125	526	527	531	535	538	540	541	542	543	544	548	Orbit		

*P - Polar
L - Low latitude
A - Any orbit
P&L - Both

1. INSTRUMENT CRITICAL TO EXPERIMENT
2. INSTRUMENT ACQUIRES USEFUL BACKUP DATA
3. DATA IS APPLICABLE BUT NOT NECESSARY

FOLDOUT FRAME 2

TABLE 2-II.- MATRIX OF EXPERIMENTS VERSUS PALLETS

Paragraph No.	Experiments title	Pallets				
		Optical/ Particle	Accelerators	Radio Frequency	Subsatellite Carrier	Special
3.1	Auroral Input-Output Experiment	X	X		X	
3.2	Electron Beam Echo Measurements of Perpendicular Electric and Magnetic Field Configurations	X	X		X	
3.3	Modification of Ionospheric Parameters and Excitation of Artificial Airglow	X	X		X	
3.4	Measurement of Parallel Electric Fields	X	X		X	
3.5	Modification of Ionospheric Conductivity using Electron Beams	X	X			
3.6	Measurement of Field Aligned (Birkeland) Currents	X		X	X	
3.7	VLF/ELF Wave Injection Experiments	X	X	X	X	
3.8	Ionospheric Heating and Coherent Scatter Radar Measurements			X		X
3.9	6 Component Measurements of Random ELF and VLF Wave Fields			X	X	
3.10	Hydromagnetic Wave Measurements				X	
3.11	ULF Antenna Measurements				X	X
3.12	Modification of Magnetospheric Bulk Flow	X			X	X
3.13	Cold Plasma Injection	X		X		X
3.14	Trace Polar Wind and Transport	X				X
3.15	Electric Field Measurements Using Multiprobes	X			X	
3.16	Trace Magnetospheric Particle Access and Motion	X		X	X	X
3.17	Magnetic Field Configuration Studies using Shaped Charge Alkali Metal Releases	X			X	X
3.18	Creation of Plasmasphere Density Ducts			X	X	X
3.19	Generation of Upper Atmosphere Gravity Waves	X			X	X

TABLE 2-II.- MATRIX OF EXPERIMENTS VERSUS PALLETS - Concluded

Paragraph No.	Experiments title	Pallets				
		Optical/ Particle	Accelerators	Radio Frequency	Subsatellite Carrier	Special
4.1	Interaction of Electron and Ion Beams with Ambient Plasma	X	X			
4.2	Plasma EMF Experiment	X	X		X	X
4.3	ELF/VLF Antenna Measurements		X	X	X	
4.4	Resonance Cone Techniques		X	X		
4.5	High Frequency Electrostatic Wave Experiments using Grid Antennas			X		
4.6	Long Delayed Echos	X		X	X	
4.7	Radio Frequency Sounder			X	X	
4.8	Lower Hybrid Resonance Experiments			X		
4.9	Pulse Propagation and Group Delay			X	X	
4.10	Plasma Neutral Gas Interaction (Critical Velocity Problem)	X		X	X	X
4.11	Creation of an Artificial Comet	X			X	X
4.12	Plasma Flow Interactions with Target Bodies	X	X		X	X
4.13	Sounding the Shuttle Wake and Natural Ionospheric Irregularities with Bistatic Doppler Tracking					X

TABLE 2-III.- INSTRUMENT ASSIGNMENTS BY PALLET

1. Particle and Optical Pallet

   (a) AMPS Instrument Module (AIM) Package

      (1) Optical Band Imager and Photometer System - 534

      (2) Medium Energy Ion Mass Analyzer - 540

   (b) Twenty (20) - Meter Boom

      (1) Neutral Mass Spectrometer - 121

      (2) Photoelectron/Secondary Electron Spectrometer - 526

      (3) Langmuir Probe - 527

      (4) Energetic Ion Mass Analyzer - 529

      (5) Ion Mass and Distribution Analyzer - 537

      (6) Energetic Ion Detector - 541

      (7) Medium Energy Ion Detector - 542

      (8) Energetic Electron Detector - 543

      (9) Medium Energy Electron Detector - 544

      (10) Vector Magnetometer - 548

2. Particle Accelerator Pallet

   (a) Pallet-mounted

      (1) Ion Accelerator - 301

      (2) Electron Accelerator - 303

      (3) Magnetoplasmadynamic (MPD) Arc - 304

      (4) High-Voltage Plasma Accelerator - 306

      (5) SEPAC Accelerator

      (6) Level I Plume Diagnostics (Gas Plume Release) - 549

TABLE 2-III.- Concluded

(b) Maneuverable - Boom mounted

(1) Level II Beam Diagnostics Group - 550

(2) Level III Beam Diagnostics Group - 551

3. Radio Frequency Pallet

(a) AMPS Instrument Module (AIM) Package

(1) RF Sounder - 405

(2) VLF Antenna and Transmitter - 418

(b) Twenty (20) - Meter Boom

(1) ELF/VLF Receivers - 411/416

(2) Dc Electric Fields - 535

(3) Resonance Cone - 417

(4) Vector Magnetometer - 548

(5) VLF Quadrupole Probe - 415

4. Subsatellite Pallet

(a) Radio Frequency Subsatellite

(b) Particle Detector Subsatellite

(c) Throw-Away Devices (TAD) Launcher

3.0 MAGNETOSPHERIC EXPERIMENTS DESCRIPTION

3.1 AURORAL INPUT-OUTPUT EXPERIMENT

3.1.1 Scientific Objectives

The purpose of this experiment will be to study the interaction of Orbiter-injected energetic particles with the atmosphere for a variety of particle types, energies, and pitch angles. The experiment will give detailed information on processes that take place in the natural aurora including emissions, ionospheric density changes, Joule heating, and electron backscatter.

3.1.2 Methods

Particle beams will be injected from the Orbiter down magnetic field lines into the atmosphere. The Electron Accelerator (Instrument 303)[1] and the Ion Accelerator (Instrument 301)[1] will be used for the particle injection. Particle energies will be varied to study the depth of atmospheric penetration. Emissions stimulated by the precipitating particles will be measured from the Orbiter by OBIPS (Optical band imager and photometer system) (Instrument 534). Backscattered particles will be measured by particle detectors on a subsatellite. In addition, particle injection can be planned so as to be carried out over various ground stations (e.g. Chatanika) where the ionospheric effects can be measured.

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[1]Experiment calls for 40 keV maximum energy. Instruments 303 and 301 go to 30 keV and 20 keV, respectively.

3.1.3 Typical Instruments

The following table shows the instruments that will be located on the Orbiter and on the subsatellite.

INSTRUMENTS SUPPORTING EXPERIMENT

Instrument no.	Instrument title	Instrument priority
	ORBITER	
122	UV-VIS-NIR Spectrometer	2
301	Ion Accelerator	2
303	Electron Accelerator	1
548	Vector Magnetometers	1
549	Level I Beam Diagnostics	1
550	Level II Beam Diagnostics	1
534	Optical Band Imager and Photometer System	1
	PARTICLE DETECTOR SUBSATELLITE	
526	Photoelectron/Secondary Electron Spectrometer	2
548	Vector Magnetometer	1
527	Langmuir Probe	1
544S	Medium Energy Electron Detector	1
543S	Energetic Electron Detector	2
540S	Medium Energy Ion Mass Analyzer	2

3.1.4 Orbit and Timeline Constraints

A polar orbit is required. The Orbiter and subsatellite altitude will probably be 400 km. Operation of the accelerators would occur at latitudes greater than 45 degrees north and south. Coordination with ground observation sites will be necessary.

3.1.5 Problem Areas

Although the experiment calls for energies somewhat higher than instruments 301 and 303 can provide, probably 95 percent of the objectives can be accomplished with these instruments. The electron accelerator will be more important than the ion accelerator because the ion beam will spread out significantly due to charge exchange causing a low intensity (auroral) output which may be hard to see against the general background.

3.2 ELECTRON BEAM ECHO MEASUREMENTS OF E AND MAGNETIC FIELD CONFIGURATION

3.2.1 Scientific Objectives

This experiment will study, in a controlled manner, dynamical processes which occur as a result of the interaction of streams of electrons with the background plasma medium as well as with electric and magnetic fields. Such processes are responsible for precipitating electron streams which cause auroral storms and may give rise to current systems which trigger substorms.

3.2.2 Proposed Methods

The technique for accomplishing the scientific objectives consists of injecting electrons into the magnetosphere by means of an onboard accelerator. An accelerator capable of outputting 1 to 10 amperes at 20 to 40 keV energy will be required. By varying the injection energy and pitch angle and by injecting at various latitudes, access of the beam to distant points of the magnetosphere can be accomplished. Pulsing of the beam will allow sorting out the beam electrons from background particles and will allow measurement of the length of magnetic field lines by measuring the time-of-flight from the injection point to the conjugate reflection point and back. Location of the return pulse in space will measure the magnetic and electric drift. By carrying out these measurements as a function of latitude and local times, it should be possible to delineate the magnetospheric cusp regions which separate the field

regions connecting with the magnetospheric tail from those which connect back to the opposite hemisphere. As the beams will pass through the portion of the magnetosphere connecting with the auroral zone, the electrodynamics of magnetic storms and substorms may be studied in detail by this technique. The beam echoes will be detected by direct particle detection and, in those portions of the orbit where echoes may be made to re-enter the atmosphere, by optical means.

3.2.3 Typical Instruments

The following table shows the instruments that will be carried on the Orbiter and the subsatellite and the priority associated with that instrument.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
303	Electron Accelerator	1
549	Level I Beam Diagnostic	1
550	Level II Beam Diagnostic	1
534	Optical Band Imager and Photometer System	1
526	Photoelectron/Secondary Electron Spectrometer	2
544	Medium Energy Electron Detector	1
543P	Energetic Electron Detector	3
548	Vector Magnetometers	1
537	Ion Mass and Distribution Analyzer	2
540P	Medium Energy Ion Mass Analyzer	3
542P	Medium Energy Ion Detector	3

Instrument no.	Instrument title	Instrument priority
	ORBITER	
529	Energetic Ion Mass Analyzer	3
541P	Energetic Ion Detector	3
	PARTICLE DETECTOR SUBSATELLITE	
121	Neutral Mass Spectrometer	3
125	Neutral Temperature and Wind Drift Spectrometer	3
526	Photoelectron/Secondary Electron Spectrometer	1
527	Langmuir Probe	1
531	Energetic Ion Mass Analyzer for AMPS Subsatellite	3
535	Dc Electric Field	1
538S	Subsatellite Ion Mass and Distribution Analyzer	2
540S	Medium Energy Ion Mass Analyzer	3
541S	Energetic Ion Detector	3
542S	Medium Energy Ion Detector	2
543S	Energetic Electron Detector	2
544S	Medium Energy Electron Detector	1
548	Vector Magnetometers	1

3.2.4 Orbit and Timeline Constraints

Both polar and low inclination orbits will be required. The polar orbits will give latitudinal effects while the low inclination orbits will allow measurements as a function of local time.

3.2.5 Problem Areas

A definite operational problem will exist in trying to use optical instrumentation aboard the Orbiter for auroral observations of the return electrons during the echo experiments. For electron injection up a field line, the Orbiter payload bay must be pointed nearly vertically upwards, whereas the optical equipment would have to look down to see the aurora. These measurements will perhaps have to be made by ground-based observations only, or from a subsatellite.

3.3 MODIFICATION OF IONOSPHERIC PARAMETERS AND EXCITATION OF ARTIFICIAL AIRGLOW

3.3.1 Scientific Objectives

This experiment will investigate the global ionospheric wind system in the F-region (200 to 300 km). In addition, it will trace and measure geomagnetic field lines and electric fields. Investigations of various plasma instabilities such as vortex-forming current sheets, drift waves and cross-field instabilities will also be carried out.

3.3.2 Proposed Methods

Injection techniques using an Orbiter-mounted plasma generator will be utilized. By injecting high density (10^{20} to 10^{21} particles) plasma bursts of 10 to 1000 eV (total energy 10 kJ per burst), the ionosphere can be locally heated and an explosive infrasonic shock wave will result. The plasma stream and shock wave will react with neutral atmospheric gas producing artificial airglow by the excitation of OI-6300Å. This excited state has a lifetime of 110 seconds and can thus be used as a tracer to investigate the dynamics of the neutral atmosphere. By firing the plasma generator at appropriate intervals along the Shuttle orbit, a trail of such luminous clouds will result. These can be tracked by Orbiter, aircraft, and ground-based optical instrumentation.

If one uses barium ions as the source in the plasma generator and injects along magnetic field lines, then one can optically trace the magnetic field line configuration and drifts caused by electric fields by observing the 4554Å resonance line, caused by scattered sunlight in the barium cloud. The plasma instabilities produced in the ionosphere by the injection can also be investigated from the spatial and temporal variations of the luminous trails produced, and the modified ionospheric parameters such as electron density and temperature determined by ionosondes, incoherent scatter radar, and various radio propagation techniques in the HF and VLF ranges.

3.3.3 Typical Instruments

The following table shows the instruments that will be carried on the Orbiter, and the particle detector and radio frequency subsatellites. The table also shows the priority of each instrument.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
122	UV-VIS-NIR Spectrometer	2
304	MPD Arc	1
306	High Voltage Plasma Gun	2
546	Plasma Accelerator[1]	2
548	Vector Magnetometers	1
534	Optical Band Imager and Photometer System	1
	PARTICLE DETECTOR SUBSATELLITE	
527	Langmuir Probe	2
526	Photoelectron/Secondary Electron Spectrometer	1

[1] Plasma Accelerator may be substituted for instruments 304 and 306.

Instrument no.	Instrument title	Instrument priority
	PARTICLE DETECTOR SUBSATELLITE	
544S	Medium Energy Electron Detector	1
543	Energetic Electron Detector	3
538S	Subsatellite Ion Mass and Disbribution Analyzer	1
540S	Medium Energy Ion Mass Analyzer	1
548	Vector Magnetometers	1
535	Dc Electric Field	1
	RADIO-FREQUENCY SUBSATELLITE	
530	HF Quadrupole Probe	2
411	ELF/VLF Receiver	3
555	Dc Electric Field	1

3.3.4 Orbit and Timeline Constraints

Both 45° and 90° inclination orbits are required with an operational altitude between 200 and 500 km. The subsatellite would fly below and slightly trailing the Orbiter. Close coordination will be required with ground- and aircraft-based optical and RF observation sites and with incoherent scatterer radar sites.

3.4 MEASUREMENTS OF PARALLEL ELECTRIC FIELDS

3.4.1 Scientific Objectives

This experiment seeks to determine if electric fields exist parallel to the magnetic lines and, if present, to measure the electric fields. Although it had been believed that such fields did not exist, there is considerable evidence that they do exist.

3.4.2 Proposed Methods

Electrons or ions are injected upward along the magnetic field. A parallel electric field of the right polarity will reflect the particles below a certain energy limit back into the atmosphere where the resulting emissions are detected. Varying the energy and pitch angle of the beam causes a variation in the space and time of the emitted light, permitting the distribution of the electric field in altitude to be determined. Alternately, a particle beam could be directed downward into the atmosphere and the energy spectrum of the particles producing the aurora could be deduced by measuring the light produced. Knowing the difference between the final and injected energies and the time between injection and light production will allow an estimation of the electric field. Optical detection is performed by OBIPS. Improved discrimination against ambient light may be obtained by pulsing the beam and integrating the measured luminosity over a time interval corresponding to the length of the pulse. It may also be feasible to position a satellite with charged particle detectors in a suitable location trailing the Orbiter to detect the reflected particles.

3.4.3 Typical Instruments

The following table shows the instruments that will be carried on the Orbiter and the particle detector subsatellite and the priority of each instrument.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
122	UV-VIS-NIR Spectrometer	2
301	Ion Accelerator	1
303	Electron Accelerator	1
529	Energetic Ion Mass Analyzer	3
534	Optical Band Imager and Photometer System	1
540	Medium Energy Ion Mass Analyzer	2

Instrument no.	Instrument title	Instrument priority
	ORBITER	
541	Energetic Ion Detector	3
542	Medium Ion Detector	2
543	Energetic Ion Detector	3
537	Ion Mass and Distribution Analyzer	1
544	Medium Energy Electron Detector	1
548	Vector Magnetometer	1
549	Level I Beam Diagnostic (Gas Plume Release)	1
550	Level II Beam Diagnostic Group	1
	PARTICLE DETECTOR SUBSATELLITE	
526	Photoelectron/Secondary Electron Spectrometer	2
527	Langmuir Probe	3
531	Energetic Ion Mass Analyzer for AMPS Subsatellite	3
535	Dc Electric Field	2
538S	Subsatellite Ion Mass and Distribution Analyzer	3
540S	Medium Energy Ion Mass Analyzer	2
541S	Energetic Ion Detector	3
542S	Medium Energy Ion Detector	3

Instrument no.	Instrument title	Instrument priority
	PARTICLE DETECTOR SUBSATELLITE	
543S	Energetic Electron Detector	3
544S	Medium Energy Electron Detector	1
548	Vector Magnetometers	1

3.4.4 Orbit and Timeline Constraints

This experiment may be performed in any orbit or location, but preferably in the polar regions and at a low altitude.

3.5 MODIFICATION OF IONOSPHERIC CONDUCTIVITY USING ELECTRON BEAMS

3.5.1 Scientific Objectives

The purpose of this experiment is to increase the ionospheric Pedersen conductivity to investigate the role of the ionosphere in controlling magnetospheric convection. The results of the experiment should give a definitive answer to the question: are electric field reductions in regions of intense particle precipitation the result of magnetospheric processes associated with the increased particle precipitation; or does the enhanced Pedersen conductivity produced by the particle precipitation actually allow the ionosphere to effectively short out the magnetospheric electric field.

3.5.2 Proposed Methods

The experiment will utilize the electron accelerator to inject eletrons downward into the atmosphere to increase the electron density in the 100- to 120-km altitude region. A 10-ampere beam at 5- to 10-keV energy is required with a pulse duration of 2 seconds. The injection will be performed over selected sites where ground-based balloon-borne or barium-release electric-field measurements can be conducted. Ground-based auroral imaging can also be used to monitor the motion of the associated artificial aurora, and hence of the ionization cloud.

3.5.3 Instruments Required

The following table shows the instruments that will be carried in the Orbiter.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
303	Electron Accelerator	1
534	Optical Band Imager and Photometer System	1
548	Vector Magnetometers	1
549	Level I Beam Diagnostic	1
550	Level II Beam Diagnostic	1

3.5.4 Orbit and Timeline Constraints

The experiment would require a polar orbit with operations being carried out at high latitudes only. Coordination with ground-, rocket-, and balloon-borne instrumentation is required.

3.6 MEASUREMENT OF FIELD ALIGNED (BIRKELAND) CURRENTS

3.6.1 Scientific Objectives

The overall purpose of this experiment is to understand the production of instabilities and energetic particles by large-scale currents or vice-versa. This will be accomplished by:

a) The detail mapping of parallel currents over a range of latitudes which covers the auroral zone and covers the current systems on a scale of hundreds of kilometers associated with the entire auroral zone and also on a scale of approximately 10 kilometers associated with individual aurorae.

b) Mapping the association of these currents with auroral morphology i.e., discrete, diffuse, and proton aurora.

c) Measuring plasma and energetic particle parameters inside and outside these currents, particularly at their boundaries. Also included are measurements of the electromagnetic frequency spectrum up to and including electron cyclotron and plasma frequencies, particularly at the current(s) boundaries.

3.6.2 Proposed Methods

Three throw-away magnetometers (TAM's) flying in close formation will be utilized to measure the magnetic field $\vec{B}$ at their respective locations from which can be derived $\vec{\nabla} \times \vec{B}$ which are used to obtain the current density. The TAM's would be released at low latitude and would stay close enough to each other for one or two high-latitude passes. A one-way telemetry link from the TAM's to the Orbiter would be necessary. Tracking of the TAM's would be accomplished with Orbiter-mounted equipment. Particle and electromagnetic frequency spectrum measurements would be accomplished with Orbiter-mounted electron and ion detectors, and wave receivers, respectively. Auroral imaging would be carried out by Orbiter optical instrumentation.

3.6.3 Typical Instruments

The following table shows the instruments that will be carried on the Orbiter.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
537	Ion Mass and Distribution Analyzer	2
542P	Medium Energy Ion Detector	2
541P	Energetic Ion Detector	3
526	Photoelectron/Secondary Electron Spectrometer	3

Instrument no.	Instrument title	Instrument priority
	ORBITER	
544	Medium Energy Electron Detector	2
543P	Energetic Electron Detector	2
527	Langmuir Probe	3
548	Vector Magnetometers	1
405	Radio Frequency Sounder	2
411	ELF/VLF Receiver	2
116	Airglow Spectrograph	3
122	UV-VIS-NIR Spectrometer	2
534	Optical Band Imager and Photometer System	1

Also required are 3 Vector Magnetometers (Instrument 548) configured as throw-away devices with a one-way telemetry link to Orbiter.

3.6.4 Orbit and Timeline Constraints

A polar orbit is required for the experiment. The three TAM's will be spun up and deployed from the Orbiter at low latitudes with mutual separation of approximately 10 km. The TAMs may have any mutual alignment except that they must not be aligned either horizontally or vertically. The location in altitude is important, but it is not known at the present time what altitude is optimum. The TAM's will require a pointing accuracy of 0.1 to 0.25 degree. Coordination with ground-based measurements of auroral, magnetic, and electromagnetic anomalies will be important for proper analysis of the experimental data.

3.6.5 Problem Areas

As was stated in paragraph 2.6.4, the optimum operational altitudes are unknown. Experiments to be conducted before the 1980-81 time frame may answer all questions which this experiment raises or may at least give an idea of the altitudes involved. If not, the use of throw-away devices may not be suitable and the magnetometers would have to be flown on maneuverable subsatellites to effect orbital changes during the experiment.

3.7 VLF/ELF WAVE INJECTION EXPERIMENTS

3.7.1 Scientific Objectives

The objectives of this experiment are:

a) To determine the basic mechanisms through which waves and energetic particles interact in the magnetosphere;

b) To carry out remote probing of the inner magnetosphere ($2 \le L \le 10$) (where L is MacElwain's parameter which names the magnetic shell); and,

c) To provide diagnostic support for AMPS cold-plasma injection and plasmasphere-density-ducts studies.

3.7.2 Proposed Methods

All three objectives will be carried out by wave injection utilizing an Orbiter-mounted VLF/ELF transmitter feeding a long dipole and/or large loop antenna. The transmitter power required is approximately 10 kW peak and the antenna dimensions would be $\le$ 100 meters tip to tip.

To accomplish objective a, the antenna would be oriented to inject appreciable wave energy up along a magnetic field line to the magnetic equatorial plane where the waves will interact with energetic electrons through the mechanism of cyclotron resonance. In this interaction, the injected waves are amplified, other VLF/ELF emissions are produced and electrons suffer pitch angle scattering with some of them entering the loss cone. The injected waves plus emissions travel to the conjugate hemisphere where they may be observed by ground stations or satellites. A significant fraction of the wave energy is reflected and will return to the vicinity of the Orbiter where observations can be carried out on a low-noise subsatellite. Energetic particles which enter the loss cone

can be observed both directly by particle detectors on the Orbiter and indirectly by the optical emissions produced upon precipitation into the atmosphere. The latter phenomenon can be observed with Orbiter-mounted optical instruments and from the ground.

In situ wave particle interactions can be carried out by simultaneous injection of VLF/ULF waves and particle beams from onboard accelerators.

Objective b would be carried out in a manner similar to that for objective a, except that the injected wave pulses would be tailored to eliminate emission effects to produce a cleaner signal. The injected waves would possess a wide range of wave-normal directions which would produce multipath propagation to points in the conjugate hemisphere. Ground stations in the conjugate hemisphere would detect ducted and, in some situations, unducted signals. Satellites would detect both ducted and unducted signals. Measurements of the time delay of the ducted signals and the time delay and wave-normal direction of the unducted signals would allow the plasma density to be determined throughout a large volume of the magnetosphere. Observations of return signals aboard the Orbiter would yield density information in its vicinity.

Objective c would be accomplished utilizing the techniques outlined in the previous paragraph.

3.7.3 Instruments Required

The following table shows the instruments that will be carried on the Orbiter and the radio frequency subsatellite.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
301	Electron Accelerator	1
303	Ion Accelerator	2
418	VLF Antennas and Transmitters	1
548	Vector Magnetometers	1
534	Optical Band Imager and Photometer System	1

Instrument no.	Instrument title	Instrument priority
	ORBITER	
526	Photoelectron/Secondary Electron Spectrometer	2
544P	Medium Energy Electron Detector	2
543P	Energetic Electron Detector	3
537	Ion Mass and Distribution Analyzer	3
540P	Medium Energy Ion Mass Analyzer	3
529	Energetic Ion Mass Analyzer	3
542P	Medium Energy Ion Detector	3
541P	Energetic Ion Detector	3
549	Level I Beam Diagnostic	1
550	Level II Beam Diagnostic	2
	RADIO FREQUENCY SUBSATELLITE	
411	ELF/VLF Receiver	1

3.7.4 Orbit and Timeline Constraints

A polar orbit is required. The subsatellite would trail the Orbiter by approximately 10 to 100 km. Coordination with ground stations will be required.

3.7.5 Problem Areas

It is questionable if objective a can be met with a simple dipole or loop antenna as these antennas are not unidirectional. An array of some type which would concentrate the RF energy along field lines should be considered.

3.8 IONOSPHERIC HEATING AND COHERENT SCATTER MEASUREMENTS

3.8.1 Scientific Objectives

The objective of this experiment is to heat the ionosphere sufficiently to produce parametric interactions involving ordinary and extraordinary waves, and Langmuir and ion acoustic waves and measure the k and w spectrum of the waves participating in the interactions.

3.8.2 Proposed Methods

It has already been demonstrated that ground-based sounders can heat the ionosphere to produce parametric interactions. Operation from the topside will greatly extend such experimentation and extend knowledge of the ionosphere.

A sounder will be used to transmit pulses at frequencies 10 to 20 percent above the local plasma frequency to insure excitation of interactions remote from the Orbiter. Peak power output will be about 50 kW with a pulse width of approximately 10 ms. A coherent scatter radar will be used to measure the interactions created by the sounder. It will transmit at several frequencies, between 20 and 50 MHz receiving energy backscattered by nonthermal density fluctuations caused by the heating wave.

3.8.3 Instruments Required

The following table shows the instruments on the Orbiter and their priority.

Instrument no.	Instrument title	Instrument priority
534	Optical Band Imager and Photometer System	3
405	Radio frequency Sounder	1
410	Coherent Scatter Radar	1
526	Langmuir Probe	3
537	Ion Mass and Distribution Analyzer	2

3.8.4 Orbit and Timeline Constraints

There will be no constraints as to the type of orbit or timeline limitations for this experiment. Transmitting times of the two instruments will not be simultaneous.

3.8.5 Problem Areas

The feasibility of this experiment requires more analysis. It is not clear cut that the experiment can be done as proposed. Although it should be possible to heat the ionosphere with the sounder, the antenna is not directional and its affect is not concentrated. The sounder could be operated, but any affect on the plasma would be weak and short lived so that it could not be seen for more than a few seconds.

Another method of performing this experiment would be to heat the plasma with the sounder and measure local effects with the Langmuir Probe and Low Energy Ion Mass Spectrometer.

3.9 SIX-COMPONENT MEASUREMENTS OF RANDOM ELF AND VLF WAVE FIELDS

3.9.1 Scientific Objective

The objective is to measure the weakly-turbulent electromagnetic wave fields in space in the 0.7 to 20 kHz frequency range. The amplitude versus frequency distribution is measured for the three electric and three magnetic components. This information is useful in identifying wave-source mechanisms and understanding energetic-particle diffusion.

3.9.2 Proposed Methods

The six components of the electromagnetic wave fields are measured simultaneously by three orthogonal electric dipoles and three orthogonal ferrite-cored loops. A real-time presentation of the spectrum of one component or cross-spectrum of two components is monitored to adjust the controls of the spectrum analyzer. Six auto-correlation spectra, 15 cross-correlation spectra and 15 quadrature spectra of the latter are computed and recorded. If the EMI is too great, mounting on a satellite may be necessary.

3.9.3 Instruments Required

The following table shows the instruments on the Orbiter and the radio frequency subsatellite and their priority for use.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
411/416	Six Component Measurements of VLF Wave Fields	1
548	Vector Magnetometers	1
	RADIO FREQUENCY SUBSATELLITE	
411	ELF/VLF Receiver	2
555	Dc Electric Field	2

3.9.4 Orbit and Timeline Constraints

The experiment can be performed in any orbit and at any altitude, however, the most useful data will be obtained in apolar orbit.

3.10 HYDROMAGNETIC WAVE MEASUREMENTS

3.10.1 Scientific Objectives

The primary objective of this experiment is to systematically study the propagation of natural hydromagnetic waves (0.01 to 10 Hz) within the ionospheric waveguide (100 to 1,000 km) to assess the hydromagnetic energy transmission between the magnetosphere, where it is presumably generated, and the ground where it is routinely monitored. A secondary objective is the measurement of field variations caused by ionospheric currents of anomalies in the terrestrial field, and measurement of the local ULF electromagnetic interference around the Orbiter.

3.10.2 Proposed Methods

This experiment will be accomplished by measuring the time variations of the ambient magnetic field, using vector magnetometers. Because of the low amplitude (10^{-6} of the geomagnetic field) of the waves, a local EMI below 0.03 gammas is required, thus making operation from a subsatellite necessary. To sort out secondary effects such as local ionospheric currents and ground magnetic anomalies, an array of such subsatellites would be desirable and comparison data from ground network measurements is essential.

3.10.3 Typical Instruments

One or more spin stabilized subsatellites with low spin rates (0.01 to 0.1 rps) equipped with Vector Magnetometers (Instrument 548) would be required. These subsatellites are called TAM's. In addition, ground-based magnetic field measurements would be necessary.

3.10.4 Orbit and Timeline Constraints

The experiment would be performed on both low and high inclination orbits. Altitudes will be between 200 and 400 km. The altitude of the subsatellite(s) must be known to within 0.5 degree in all three axes. The position of the subsatellite(s) should be known to within a few kilometers. Instrument operation will be continuous, and coordination with ground station measurements is essential.

3.10.5 Problem Areas

The triaxial fluxgate, is probably not sensitive enough to accomplish all of the experimental objectives at the present state-of-the-art. However, vapor magnetometers, configured with triaxial bias coils, should be satisfactory.

3.11 ULF ANTENNA MEASUREMENTS

3.11.1 Scientific Objectives

The ultimate aim of this experiment is to study the generation and propagation of ULF waves (0.1 to 5 Hz) in the ionosphere by means of artificial injection from a long-wire-dipole or monopole antenna. Such an experiment would enable the separate identification of generation and

propagation effects in the phenomenology of natural micropulsations. Other related issues which can be investigated include the ionospheric shielding effect at ULF frequencies and the excitation from F2 layer heights of ULF guided waves in the earth-ionosphere cavity. An immediate objective is the study of the properties of the long antenna embedded in an unbounded magnetoionic plasma. These include the phenomenon of the plasma sheath around the antenna and its blowing out because of the applied field. Also the electrodynamics of the antenna wire itself as a conductor that moves in the earth's magnetic field could be investigated without the use of a transmitter.

3.11.2 Methods

The experimental technique involves deployment of a long (10 to 100 km) monopole or dipole wire antenna, in a quasi-vertical configuration, stabilized by the gravity gradient effect. After the wire's deployment, the electrodynamic and electromagnetic behavior of the wire (with and without excitation from the Orbiter-borne transmitter) will be monitored by measuring the wire current, voltage, and base impedance with an Orbiter-mounted test set. The propagation properties of the artificial micropulsations generated by the wire will be established by ground observations in magnetically conjugate regions and in other regions of interest, and from a subsatellite at near and far distances from the wire.

3.11.3 Instruments Required

The following table shows the instruments on the Orbiter and radio frequency subsatellite, as well as the priority of each instrument.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
407	ULF Antenna/Transmitter	1
408	Tethered Subsatellite[1]	1
548	Vector Magnetometer	1
	RADIO FREQUENCY SUBSATELLITE	
411	ELF/VLF Antenna	2

Note: 1. Subsatellite may be free flying.

3.11.4 Orbit and Timeline Constraints

A polar orbit would be required for this experiment. The subsatellite would be required to make measurements in selected sectors around the wire near to and far away from the wire. Coordination with ground-observations stations will be required.

3.11.5 Problem Areas

Details of the method of deployment and retrieval of the 100 km tether still need to be worked out. During deployment and retrieval and also while deployed, the tether will restrict the maneuvering of the Orbiter significantly.

3.12 MODIFICATION OF THE MAGNETOSPHERIC BULK FLOW

3.12.1 Scientific Objectives

This experiment will seek to clarify magnetospheric and ionospheric interactions by perturbing the lower F Region of the ionosphere. Ionization enhancement and depletion will be studied separately as will the effect of a neutral wind on the local plasma.

3.12.2 Proposed Methods

Large (100 to 1000 kg) chemical releases will be made at low (135 to 200 km) altitudes where the Pedersen component of the anisotropic conductivity matrix is large. Three classes of chemicals are desirable: ionization enhancers such as barium; electron getters (possible sulfur hexafluoride); and neutral gases (nitrogen and hydrogen are possible candidates). Barium (or other alkalai metals) will be released in a thermite reaction and ionized by sunlight. Fixed gases will be valved from high-pressure flasks. Release tracks will extend about 1000 km. Tracks both parallel and perpendicular to the horizontal electric field are of scientific interest. The chemical canisters will be carried into orbit by the Orbiter and driven down to the release point by solid fuel separation rockets. Particularly in the case of the neutral gas release, the kinetic energy of orbital velocity will be used to drive an ionospheric magnetohydrodynamic "dynamo" which should bring about a local field and current reversal in the ambient plasma.

3.12.3 Typical Instruments

The following table shows the instruments on the Orbiter and particle Detector Subsatellite, as well as the instrument priority.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
121	Neutral Mass Spectrometer	3
527	Langmuir Probe	3
529	Energetic Ion Mass Analyzer	3
534	Optical Band Imager and Photometer System	1
537	Ion Mass and Distribution Analyzer	2
540P	Medium Energy Ion Mass Analyzer	2
541P	Energetic Ion Detector	3
542P	Medium Energy Ion Detector	2
543P	Energetic Electron Detector	3
544P	Medium Energy Electron Detector	2
548	Vector Magnetometers	1
544	Chemical Release Module	1
557	Booster Firing Capability	1
	PARTICLE DETECTOR SUBSATELLITE	
121	Neutral Mass Spectrometer	1
125	Neutral Temperature and Wind Drift Spectrometer	2

Instrument no.	Instrument title	Instrument priority
	PARTICLE DETECTOR SUBSATELLITE	
526	Photoelectron/Secondary Electron Spectrometer	1
527	Langmuir Probe	2
531	Energetic Ion Mass Analyzer	2
535	Dc Electric Field	2
548	Vector Magnetometers	1
540S	Medium Energy Ion Mass Analyzer	1
541S	Energetic Ion Detector	2
542S	Medium Energy Ion Detector	2
543S	Energetic Electron Detector	2
544S	Medium Energy Electron Detector	2
538S	(Subsatellite) Ion Mass and Distribution Analyzer	1

3.12.4 Orbit and Timeline Constraints

The Orbiter and PDSS (Particle Detector Subsatellite) would be nominally in 200 km orbits at an inclination high enough to reach the auroral zone. The Chemical Release Module would be ejected and placed into an orbit that will carry it to an altitude of approximately 180 km. The release should be made in the region of interest such that the Orbiter and/or PDSS will pass over the release area about two minutes after the release is made. At least the first few release attempts should be performed when auroral and magnetic activity are relatively quiet. The alkalai releases must be made in sunlight. Coordination with ground-based optical, magnetic, and ionosonde facilities is required. Although high inclination orbits are required, preliminary tests could be performed at low inclinations.

3.12.5 Problem Areas

The feasibility of this experiment needs further study. Questions such as how big an area will be affected, how long the clouds last, and what are the expected flux levels need to be answered. It may also be that although the release can be carried by the Orbiter, the Orbiter and subsatellite may not be in position long enough to make meaningful measurements and that the only useful data will come from ground stations. It is imperative that questions relating to the ecological impact of such releases also be answered.

3.13 COLD PLASMA INJECTION

3.13.1 Scientific Objectives

This experiment will study the effects of cold plasma beyond the plasmapause. Verification will be sought for predictions concerning electromagnetic gyrofrequency resonant reactions. Multiple injections will be used to probe boundary conditions, scale sizes, and growth rates of predicted instabilities

3.13.2 Proposed Methods

This experiment requires placement of an artificial plasma beyond the plasmapause, at altitudes on the order of 20,000 to 40,000 km. Several alternative seeding techniques are possible. The preferred method would be from a subsatellite in an orbit at the preferred altitude with a diagnostic package to verify favorable conditions in situ. Release would be on command, probably by a thermite reaction. Alternately, the package could be boosted from the Orbiter or from the ground with a sounding rocket with a similar plasma generation method. A third alternative would be to fire a lithium-lined shaped charge from the vicinity of the Orbiter and rely on the low photoionization rate to allow a useful quantity of the metal to cross the magnetic field lines before ionizing at the desired altitude. Electromagnetic wave measurements would be performed by the Orbiter and ground installations. Ground observations would be to look for red auroral arcs caused by proton-oxygen collisions.

3.13.3 Typical Instruments

The following table shows the instruments on the orbiter and the Radio Frequency Subsatellite.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
405	Radio Frequency Sounder	1
411	ELF/VLF Receiver	1
527	Langmuir Probe	3
529	Energetic Ion Mass Analyzer	3
534	Optical Band Imager and Photometer System	1
537	Ion Mass and Distribution Analyzer	1
540	Medium Energy Ion Mass Analyzer	3
541	Energetic Ion Detector	2
542	Medium Energy Ion Detector	1
543	Energetic Electron Detector	2
544	Medium Energy Electron Detector	2
548	Vector Magnetometer	1
554	Chemical Release Module	1
557	Booster firing capability	1

Instrument no.	Instrument title	Instrument priority
	RADIO FREQUENCY SUBSATELLITE	
415	Radio Frequency Receiver (remote receiver)	1
535	Dc Electric Field	2
536	Triaxial Fluxgate	1

3.13.4 Orbit and Timeline Constraints

The Orbiter, Particle Detector Subsatellite, and Radio Frequency Subsatellite would be in nominal 400-km orbits. A low-inclination orbit would facilitate rocket boosts from the Orbiter to high altitude. A chemical release subsatellite staged from the Oribter is under consideration for the boost task. Such a vehicle could be placed in a highly elliptical orbit such that the apogee would precess from the bow shock (sunlit side) to the magnetotail (dark side) in about eight months. This would allow command release in two regions of importance with a single staging operation, but require multiple AMPS missions spaced at the correct interval. Launch and release timing for this and other release techniques requires further study for optimization of data collection. Coordination with ground-based observations will also be required for this experiment.

3.13.5 Problem Areas

The shaped-charge method which jets the lithium to altitude will probably be unsatisfactory in that in situ measurements of plasma parameters are necessary to determine the optimum release point for the lithium. Also, this type of release would seed the magnetosphere over a wide range of altitudes and this would present a problem of knowing where its effects, if any, originated. It is also somewhat questionable, regardless of the type of release, whether the Orbiter would be in the correct location (at lower altitude) to diagnose the effects.

3.14 TRACE POLAR WIND AND TRANSPORT

3.14.1 Scientific Objectives

This experiment will study plasma dynamics and ionospheric behavior, particularly the transport and acceleration processes found at high latitude.

3.14.2 Proposed Methods

The principal technique to be employed is the release of large (1,000 kg) quantities of neutral gas such as hydrogen, nitrogen or helium, or by trace ions such as alkali metals at and up to 500 km above the Orbiter level and at latitudes above 60 degrees. The released gas clouds will be tracked by radio-frequency sounding, optical photometry, and mass spectrographic probing.

3.14.3 Applicable Instruments

The following table shows the instruments on the Orbiter and the two subsatellites. Also included is the priority of each instrument.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
405	Radio Frequency Sounder	1
411	ELF/VLF Receiver	2
527	Langmuir Probe	3
529	Energetic Ion Mass Analyzer	3
534	Optical Band Imager and Photometer System	1
537	Ion Mass and Distribution Analyzer	2
540	Medium Energy Ion Mass Analyzer	2

Instrument no.	Instrument title	Instrument priority
	ORBITER	
541	Energetic Ion Detector	3
542	Medium Energy Ion Detector	2
543	Energetic Electron Detector	3
544	Medium Energy Electron Detector	2
548	Vector Magnetometer	1
554	Chemical Release Module	1
557	Booster firing capability	1
	PARTICLE DETECTOR SUBSATELLITE	
121	Neutral Mass Spectrometer	1
125	Neutral Temperature and Wind Drift Spectrometer	1
526	Photoelectron/Secondary Electron Spectrometer	2
527	Langmuir Probe	3
531	Energetic Ion Mass Analyzer for AMPS Subsatellite	3
535	Dc Electric Field	2
538S	Subsatellite Ion Mass and Distribution Analyzer	2
540S	Medium Energy Ion Mass Analyzer	2
541S	Energetic Ion Detector	3
542S	Medium Energy Ion Detector	3

Instrument no.	Instrument title	Instrument priority
	ORBITER	
543S	Energetic Electron Detector	3
544S	Medium Energy Electron Detector	2
548	Vector Magnetometers	1
	RADIO FREQUENCY SUBSATELLITE	
405	Radio Frequency Sounder (remote receiver)	2
411	ELF/VLF Receiver	1
555	Dc Electric Field	1
548	Vector Magnetometers	1

3.14.4 Orbit and Timeline Constraints

This experiment would be performed from a nominal 400-km polar orbit. The PDSS (Particle Detector Subsatellite) and RFSS (Radio Frequency Subsatellite) would be at or above the Orbiter altitude. The PDSS would be positioned to pass through the released cloud and the Orbiter through the precipitation events below the cloud. The chemical release container would be ejected at the conjugate pole and a velocity increment would be added to give an apogee 500 km above the Orbiter at the release point. The release should occur in the vicinity of the Chatanika, Alaska, sounding radar. Calculations have shown that the effects of the release may last from 30 to 900 seconds (for a 100-kg release).

3.14.5 Problem Areas

Although there is some transport downward, the most interesting data will be obtained if the PDSS can be placed at the altitude of release so that it will pass through the cloud.

3.15 ELECTRIC FIELD MEASUREMENTS USING MULTIPROBES

3.15.1 Scientific Objectives

The objective of this experiment is to disentangle temporal and spatial properties of electric fields in the ionosphere by taking simultaneous measurements at several points a few kilometers apart in the local field.

3.15.2 Proposed Methods

A number of expendable probes will be released in a loose formation or swarm. Rudimentary attitude sensing and telemetry, powered by chemical batteries, will be incorporated in the probes. Because of the low unit cost and limited lifetime, several probes would be expended each time this experiment is performed. The Orbiter and more complex subsatellites would be used for more extensive diagnosis of the ambient plasma during the experiment.

3.15.3 Instruments Required

The following table shows the instruments on the Orbiter and the PDSS (Particle Detector Subsatellite). Also shown is the priority of each instrument.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
548	Vector Magnetometers	1
555	Expendable Field Probes[1] (Electric Field Measurement)	1

[1]Three to six expendable field may be used simultaneously on each flight.

Instrument no.	Instrument title	Instrument priority
	PARTICLE DETECTOR SATELLITE	
121	Neutral Mass Spectrometer	2
125	Neutral Temperature and Wind Drift Spectrometer	2
526	Photoelectron/Secondary Electron Spectrometer	2
527	Langmuir Probe	2
531	Energetic Ion Mass Analyzer for AMPS Subsatellites	2
535	Dc Electric Field	1
538S	Subsatellite Ion Mass and Distribution Analyzer	1
540S	Medium Energy Ion Mass Analyzer	2
541	Energetic Ion Detector	3
542S	Medium Energy Ion Detector	2
543S	Energetic Electron Detector	2
544S	Medium Energy Electron Detector	2
548	Vector Magnetometers	1

Radar is necessary to know the location of each probe or subsatellite.

3.15.4 Orbit and Timeline Constraints

The Orbiter and the ejected probes will be in 400-km polar or high-inclination orbits. The PDSS should be at 200 km. Ejection sequencing and velocity imparted to the expendable probes will be computed on the basis of desirable deployment patterns and telemetry considerations.

3.16 TRACE MAGNETOSPHERIC PARTICLE ACCESS AND MOTION

3.16.1 Scientific Objectives

The objectives of this experiment are to extend the proven technique of trace ion release to points of interest at altitudes of 10 to 20 earth radii (65,000 to 135,000 km) to provide flow visualization and measurements of the entry and convection of solar wind particles into the magnetosphere. Measurements of particle energization and loss process will also be undertaken using tracer techniques.

3.16.2 Proposed Methods

Access to the region of interest should be possible by: a) large (500-kg gross weight) shaped charges that will be detonated at the Orbiter altitude and directed up high latitude field lines; b) boosted thermite canisters staged from the Orbiter; or, c) direct ground ascent. The released cloud or jet would be viewed with optical instrumentation aboard the Orbiter and return convected particles would be detected by mass spectrographic means.

3.16.3 Instruments Required

The following table shows the instruments on the Orbiter and Particle Detector Subsatellite.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
527	Langmuir Probe	3
529	Energetic Ion Mass Analyzer	1

Instrument no.	Instrument title	Instrument priority
	ORBITER	
537	Ion Mass and Distribution Analyzer	3
540	Medium Energy Ion Mass Analyzer	1
541	Energetic Ion Detector	3
542	Medium Energy Ion Detector	3
543	Energetic Electron Detector	3
544	Medium Energy Electron Detector	3
548	Vector Magnetometers	2
554	Chemical Release Module	1
534	Optical Band Imager and Photometer System	1
535	Dc Electric Field	2
411	ELF/VLF Receiver	2
526	Photoelectron/Secondary Electron Spectrometer	3
557	Booster firing capability	1
	PARTICLE DETECTOR SUBSATELLITE	
121	Neutral Mass Spectrometer	3
125	Neutral Temperature and Wind Drift Spectrometer	3
526	Photoelectron/Secondary Electron Spectrometer	2

Instrument no.	Instrument title	Instrument priority
	PARTICLE DETECTOR SUBSATELLITE	
527	Langmuir Probe	3
531	Energetic Ion Mass Analyzer for AMPS Subsatellite	1
535	Dc Electric Field	2
538S	Subsatellite Ion Mass and Distribution Analyzer	1
540S	Medium Energy Ion Mass Analyzer	2
541S	Energetic Ion Detector	2
542S	Medium Energy Ion Detector	2
543S	Energetic Electron Detector	2
544S	Medium Energy Electron Detector	2
548	Vector Magnetometers	1

3.16.4 Orbit and Timeline Constraints

The most convenient orbits for the Orbiter and PDSS (Particle Detector Subsatellite) may be 400 km, nominally circular, high inclination ones. If the release module is carried by the Orbiter, safety considerations would require at least a 10-km separation before any large shaped charges (method "a") are detonated. Method (b) would use a relatively large booster rocket. Detailed orbital mechanical calculations have not been made to determine the best sequencing of the PDDS, Orbiter, and release operations. It may be desirable to launch the release module a few orbits or days in advance of the release event.

3.16.5 Problem Areas

A similar experiment will very probably be performed before 1980-81 which will answer many of the questions of this experiment. However, this experiment will be useful as a first iteration. Releases this large

may present ecological problems. These must be assessed before the experiment is performed. Also, if the release is boosted from the Orbiter, safety problems associated with such large thermite or shaped charge packages may be incurred.

3.17 MAGNETIC FIELD CONFIGURATION STUDIES USING SHAPED CHARGE ALKALI METAL RELEASES

3.17.1 Scientific Objectives

This experiment will provide detailed information on the shape of the geomagnetic field at high values of McElwain's L parameter. This knowledge is required to relate phenomena observed in the distant magnetosphere to ionospheric phenomena. Most of the present information is based on in situ magnetometer readings made by interplanetary probes which are not capable of separating spatial and temporal changes in the field.

3.17.2 Proposed Methods

This experiment will utilize the technique of firing a shaped charge alkalai metal release up a field line. The metal vapor is photoionized by sunlight and will trap in and trace out a particular magnetic force tube. The luminous trail of the metal jet will be tracked by the Orbiter and ground-based optical instrumentation. Firings of the shaped-charge releases will probably take place from a chemical release module deployed from the Orbiter. A large number of firings will be required over a long period of time to permit a view at seasonal changes in the field which are caused by different tilts of the dipole field relative to the sun.

3.17.3 Typical Instruments

The following table shows the instruments on the Orbiter and on the PDSS.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
527	Langmuir Probe	3
534	Optical Band Imager and Photometer System	1
537	Ion Mass and Distribution Analyzer	2
542	Medium Energy Ion Detector	3
543	Energetic Ion Detector	3
544	Medium Energy Electron Detector	3
548	Vector Magnetometers	1
554	Chemical Release Module	1
557	Booster firing capability	1
529	Energetic Ion Mass Analyzer	3
540	Medium Energy Ion Mass Analyzer	3
541	Energetic Ion Detector	3
526	Photoelectron/Secondary Electron Spectrometer	3

Instrument no.	Instrument title	Instrument priority
	PARTICLE DETECTOR SUBSATELLITE	
121	Neutral Mass Spectrometer	2
125	Neutral Temperature and Wind Drift Spectrometer	3
526	Photoelectron/Secondary Electron Spectrometer	3
527	Langmuir Probe	3
531	Energetic Ion Mass Analyzer for AMPS Subsatellite	3
535	Dc Electric Field	3
538S	Subsatellite Ion Mass and Distribution Analyzer	2
540S	Medium Energy Ion Mass Analyzer	3
541S	Energetic Ion Detector	3
542S	Medium Energy Ion Detector	3
543S	Energetic Electron Detector	3
544S	Medium Energy Electron Detector	2
548	Vector Magnetometers	1

3.17.4 Orbit and Timeline Constraints

This experiment would require a high inclination orbit and sunlight. The Orbiter and PDSS would be in nominal 400-km circular orbits. The chemical release module would be deployed from the Orbiter and spun up. Chemical releases would be performed when the explosion would not pose a physical or contamination hazard to the Orbiter. Coordination with ground-based optical observation sites is required.

3.17.5 Problem Areas

The presence of the explosive releases on the Orbiter may pose a safety hazard. Also, the Orbiter will not be able to track the release while in the Earth's shadow.

3.18 CREATION OF PLASMASPHERE DENSITY DUCTS

3.18.1 Scientific Objectives

This experiment will seek to establish a large region of depleted ionization in the plasmasphere by releasing a large cloud of neutral molecules (on the order of 1000 kg of hydrogen). This cloud should deplete the ionization in connecting flux tubes, creating a RF duct or waveguide for VLF and HF signals which is expected to last for several hours if created on the night side of the earth.

3.18.2 Proposed Methods

A large gas release will be made at approximately 400 km. Excess propellant carried in the Orbital Maneuvering System could be vented into an overboard dump line to provide the required release. Orbiter measurements would be confined to radio frequency sounding.

3.18.3 Instruments Required

The following table shows the instruments on the Orbiter and a subsatellite.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
405	Radio Frequency Sounder	1
554	Chemical Release Module	1
418	VLF Antennas and Transmitters	2

Instrument no.	Instrument title	Instrument priority
	SUBSATELLITE	
405	Radio Frequency Sounder (Receiver)	1
411	ELF/VLF Receiver	1

3.18.4 Orbit and Timeline Constraints

This experiment would be performed in conjunction with ground-based ionospheric sounding installations which are within reach of low inclination orbits. Particular orbit and timeline considerations would be based on the cooperating facilities.

3.18.5 Problem Areas

The measurements may be better performed from the ground as the duct will take several minutes to form and the Orbiter may be out of range.

3.19 GENERATION OF UPPER-ATMOSPHERE GRAVITY WAVES

3.19.1 Scientific Objectives

This experiment will seek to generate an atmospheric gravity wave of traveling ionospheric disturbance (TID). Naturally occurring TID's have been observed for over a decade, but the source mechanism remains obscure because of long propagation distances and frequent occurrence. An artifically created wave would allow controlled study of damping and propagation mechanisms.

3.19.2 Proposed Methods

The artificial gravity wave will be "generated" by an abrupt release of about 1000 kg of neutral gas at an altitude of 100 to 300 km. The same neutral gas releases used for experiment 2.12, MODIFICATIONS OF THE MAGNETOSPHERIC BULK FLOW, will be used. Optical and mass spectrographic tracking will be used to follow the cloud. Small barium canisters (10 kg)

may be desirable to track the neutral cloud. Propagation of the TID will also be detected by pressure bulges found by neutron and ion mass spectrometers on the (PDSS) Particle Detector Subsatellite.

3.19.3 Applicable Instruments

The following table shows the instruments on the Orbiter and the PDSS.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
121	Neutral Mass Spectrometer	3
122	UV-VIS-VIR Spectrometer/ Photometer	3
534	Optical Band Imager and Photometer System	1
554	Chemical Release Module	1
557	Booster firing capability	1
	PARTICLE DETECTOR SUBSATELLITE	
121	Neutral Mass Spectrometer	1
125	Neutral Temperature and Wind Drift Spectrometer	1
526	Photoelectron/Secondary Electron Spectrometer	1
527	Langmuir Probe	2
531	Energetic Ion Mass Analyzer	3
535	Dc Electric Field	2
538S	Subsatellite Ion Mass and Distribution Analyzer	1

Instrument no.	Instrument title	Instrument priority
	ORBITER	
540S	Medium Energy Ion Mass Analyzer	2
541S	Energetic Ion Detector	3
542S	Medium Energy Ion Detector	2
543S	Energetic Electron Detector	3
544S	Medium Energy Electron Detector	2
548	Vector Magnetometer	1

3.19.4 Orbit and Timeline Constraints

This experiment would require a high inclination orbit. The Orbiter and PDSS will be at 200 km and the release will be made at this altitude. For optical tracing, the release would have to be made in sunlight. Coordination with ground-based observation sites is essential.

3.19.5 Problem Areas

To prevent confusion caused by magnetic-field aligned effects, it may be better to use a neutral (non-photoionizable) gas as an optical tracer.

4.0 PLASMA EXPERIMENTS DESCRIPTION

4.1 THE INTERACTION OF ELECTRON AND ION BEAMS WITH THE AMBIENT PLASMA

4.1.1 Scientific Objectives

The purpose of this experiment is to study the interactions between charged particle beams and the ambient plasma in a very large experimental volume where wall effects are minimal. The results will be used to reconcile presently available and future theories of such interactions with experimental observations. A secondary objective will be to inject the particle beams at varying pitch angles relative to the geomagnetic field and study the helical beam so produced as a radiator or virtual antenna.

4.1.2 Proposed Methods

The experiment will be performed by injecting a charged particle beam from either the Electron Accelerator (Instrument 303), the Ion Accelerator (Instrument 301), or a low energy electron source such as Instrument 552. The monoenergetic beam will spread to some equilibrium distribution by energy and momentum exchange with the ambient plasma. Detectors would be mounted on a 30-meter boom along the beam path. The boom would be articulated and varied in length to measure beam intensity spatial distribution. If the beam is velocity modulated, then the boom-mounted detectors can measure beam-plasma perturbations which are swept past them.

4.1.3 Typical Instruments

The following table shows the instruments on the Orbiter and their priority for use on this experiment.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
122	UV-VIS-NIR Spectrometer	2
301	Ion Accelerator	1
303	Electron Accelerator	1

Instrument no.	Instrument title	Instrument priority
	ORBITER	
534	Optical Band Imager and Photometer System	2
549	Gas Plume Release	2
550	Level II Beam Diagnostics	2
551	Level III Beam Diagnostics	3
548	Vector Magnetometers	1
552	Low Energy Electron Beam Experiments (Leebex)	2

4.1.4 Orbit and Timeline Constraints

The experiment can be performed either day or night. A low-inclination orbit is preferred as the ambient magnetic field changes more slowly. Operator intervention would be required to control beam modulation and boom scanning in the event of unexpected results both in beam structure and wave emissions.

4.2 PLASMA EMF EXPERIMENT

4.2.1 Scientific Objectives

The purpose of this experiment is to probe electrodynamic and plasma processes which are associated with or caused by the motion of a large conductor through the earth's magnetic field. These will include: (a) the measurement of ionospheric conductivity; (b) the generation of large amplitude Alfven waves; (c) the generation of plasma instabilities; (d) Orbiter charge neutralization; and (e) the generation of electrical power.

4.2.2 Proposed Methods

The Field-Aligned Current Generator (Instrument 553) will be used to generate an electromotive force (EMF) between its conducting balloon and the Orbiter. Pulsing of the currents flowing through the tether generate amplitude controllable Alfven waves. The Electron Accelerator (Instrument 303) and the Ion Accelerator (Instrument 301) operating individually with Instrument 553 will be required to accomplish current control. With Instruments 553 and 303 operating simultaneously and Instrument 303 supplying its accelerating potential, the possibility exists that useful power levels of several kilowatts can be generated at the expense of spacecraft orbital energy. With Instruments 526, 527, 541P, 542P, 543P, 544, and 537 mounted on the Orbiter the state of the ambient plasma in the Orbiter/balloon vicinity would be determined. Instrument 548 on the Orbiter would be used for ambient geomagnetic field determination while 549 and 550 would diagnose the accelerator beams.

4.2.3 Typical Instruments

The following table shows the instruments that are located on the Orbiter and the RFSS (Radio Frequency Subsatellite) and gives the priority, of each instrument.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
553	Field Aligned Current Generator	1
301	Ion Accelerator	1
303	Electron Accelerator	1
549	Gas Plume Release	2
550	Level II Beam Diagnostics	1
548	Vector Magnetometers	1
526	Photoelectron/Secondary Electron Spectrometer	1
527	Langmuir Probe	1

Instrument no.	Instrument title	Instrument priority
	ORBITER	
541P	Energetic Ion Detector	3
542P	Medium Energy Ion Detector	2
537	Ion Mass and Distribution Analyzer	2
543P	Energetic Electron Detector	3
544	Medium Energy Electron Detector	2
	RADIO FREQUENCY SUBSATELLITE	
555	Dc Electric Field	1
548	Vector Magnetometers	1
411	ELF/VLF Receiver	1

4.2.4 Orbit and Timeline Constraints

Both low and high inclination orbits are applicable. High inclinations are best for the conductivity and wave measurements. Low inclination eastward orbits would be best for the power generation objective, however, even on high inclination orbits, this phase of the experiment would work. Subsatellite measurements of the electromagnetic waves produced will be made out to the limits of subsatellite range, but at least 20-km away from the balloon (Instrument 553) along the same magnetic field line as the balloon. Operation of the experiment will be continuous for at least one full orbit with intermittent operation during other experiment operations. Measurements of the balloon/Orbiter potential difference should be on a continuous basis, once balloon deployment has begun.

4.2.5 Problem Areas

The method of deployment and retrieval of the balloon has yet to be worked out. During deployment, Orbiter maneuvers will be highly restricted, i.e., Orbiter payload bay must point in a generally upward direction. High current levels in the tether may result in large destabilizing forces on the tether and high heat loads for the Orbiter.

4.3 ELF/VLF ANTENNA MEASUREMENTS

4.3.1 Scientific Objectives

This experiment will be used to test existing theories of antenna impedance and radiation pattern characteristics at ELF/VLF frequencies where there is relatively poor coupling of the antenna radiation into the ambient plasma.

4.3.2 Proposed Methods

A high-power wave sounder will be used for active ionospheric and magnetospheric experiments including non-linear wave-wave and wave-particle interactions, for remote magnetospheric density diagnostics, and for communications applications. At frequencies below the electron plasma frequency, the characteristics of an orbiting antenna system are controlled by the ambient plasma and differ substantially from the equivalent free-space or ground-based cases. Because of the long wavelengths and range of plasma parameters involved, laboratory plasma facilities do not accurately model such systems below the lower hybrid resonance frequency and thus do not provide reliable measurements of such parameters as radiation resistance and efficiency, and radiation patterns. Antenna impedance and its dependence on frequency, orientation, and plasma parameters, will be determined by onboard measurements of antenna current and voltage. Measurements of such parameters as radiation patterns and efficiencies, and accelerated particle fluxes will be made using diagnostic equipment at distances from a few meters and up to several wavelengths from the Orbiter.

Three antenna concepts will be tested. They are a conventional dipole variable in length up to 300-m tip to tip, a multiturn loop with a geometric cross section of about 500 m^2; and charged-particle beam antenna.

4.3.3 Typical Instruments

The following table shows the instruments on the Orbiter and the Radio Frequency Subsatellite. Also shown is the priority of each instrument.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
301	Ion Accelerator	1
303	Electron Accelerator	1
405	Radio Frequency Sounder	1
411 or 416	ELF/VLF Receiver or Six-Component Measurements of VLF Wave Fields	1 1
548	Vector Magnetometers	1
549	Gas Plume Release	3
550	Level II Beam Diagnostics	1
	RADIO FREQUENCY SUBSATELLITE	
411	ELF/VLF Receiver	1

4.3.4 Orbit and Timeline Constraints

There are no constraints for this experiment. Radio frequency or particle emitting instruments other than those being used for this experiment should not be operated.

4.3.5 Problem Areas

Of the three antennas required, only one, the 300-m dipole, has been described in IFRD's (Instrument Functional Requirements Documents). The large multiturn loop would be no problem, technically, but a modulated neutral ion beam does not exist in the IFRD. To obtain the neutral beam, protons and electrons will be mixed. This in turn will be modulated by

modulating the grid or high voltage supply. It could also be done with a mechanical chopper placed in front of the beam.

4.4 RESONANCE CONE TECHNIQUES

4.4.1 Scientific Objectives

This experiment will develop techniques for measuring the properties of the "oblique" or "cone" resonances that occur in certain frequency bands, and will use these techniques for diagnostics of the local plasma. Electron density, temperature, and field-aligned drift velocity should be measurable in this manner.

4.4.2 Proposed Methods

The resonances are observed by propagating RF signals between two small antennas, over distances of a few meters, in directions that make oblique angles to the magnetic field. Their properties can be measured either by keeping the frequency constant and varying the angle, or by keeping the angle constant and varying the frequency.

The two small antennas will have variable separation and will be mounted on the balanced spin platform rotating at 60 to 120 rpm. The receiver will consist of a transfer function meter operating in the frequency range of 10 kHz to 10 MHz.

4.4.3 Typical Instruments

The following table shows the instruments on the Orbiter and their priority.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
417	Reasonance Cone Technique	1
537	Ion Mass and Distribution Analyzer	2
548	Vector Magnetometer	1

4.4.4 Orbit and Timeline Constraints

All feasible orbits are acceptable. There are no timeline constraints, except that other transmitting instruments that could disturb the plasma should not be operated. Plasma experiments could be done after ambient measurements are made. This would give data with a known disturbance.

4.5 HIGH FREQUENCY ELECTROSTATIC WAVE EXPERIMENTS USING GRID ANTENNAS

4.5.1 Scientific Objectives

This experiment will develop probes which will measure the ambient plasma parameters including the velocity distribution function for electrons of an energy level less than 70 eV, as well as study non-equilibrium plasmas.

4.5.2 Proposed Methods

This experiment uses an antenna consisting of two circular wire-mesh disks, parallel to one another and separated by a distance comparable with their diameter (50 to 70 cm). Two quantities are measured as functions of frequency: antenna self-impedance, using CW signals; and group velocity of electrostatic waves propagated from this antenna to another, using pulsed signals. In the group-velocity experiment, the second antenna could be of the same type, or alternatively a short dipole; its distance from the first would be variable, for instance, in the range 0 to 5 m. Frequency range transmitted would be 1 to 20 MHz. Associated electronics would include a frequency synthesizer, a pulse generator, a network analyzer, and CRO display and recording system.

4.5.3 Typical Instruments

The following table shows the instruments on the Orbiter and the priority of the instruments.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
421	Group Velocity Measurement	1
527	Langmuir Probe	2
537	Ion Mass Spectrometer	2
548	Vector Magnetometer	1

4.5.4 Orbit and Timeline Constraints

This experiment should be operated in an equatorial orbit of moderate inclination at an altitude of below 250 km. Its timeline should be established so that EMI and disturbance of the plasma are at a minimum. The spacecraft pointing accuracy is plus or minus 10° and the attitude should be such that the antennas are leading the spacecraft, or at least, out of any disturbance in the plasma wake.

4.6 LONG-DELAYED ECHOES

4.6.1 Scientific Objectives

This experiment will use a sounder to transmit and measure radio echoes having delays on the order of tens of seconds when reflected from the ionosphere in an effort to explain the phenomenon.

4.6.2 Proposed Methods

The long-delay RF echo phenomenon is difficult to study with ground-based transmitters because of frequency constraints and heavy radio traffic. This experiment can avoid these problems. An RF sounder will be used to transmit CW signals of 100 ms length at a frequency of 10 MHz with a pulse repeated at regular intervals of approximately 30 seconds.

Reflected signals will be monitored on a long-persistence CRO and recorded on an audio tape recorder. The sounding frequency will be varied near to and below the ordinary mode perturbation frequency for the ionospheric F-layer. Simultaneous observations will be made with an electron velocity analyzer to determine whether energetic electrons (1 keV) are being precipitated when long-delayed echoes are being observed.

4.6.3 Typical Instruments

The following instruments are planned to be used for this experiment. The number following the experiment indicates the priority of that instrument.

405 Radio Frequency Sounder - 1

544 Medium Energy Electron Detector - 2

544S PDSS Medium Energy Electron Detector - 2

4.6.4 Orbit and Timeline Constraints

There should be no orbital constraints to this experiment although equatorial orbits may be preferred to polar orbits. Timelines should be established so that EMI problems in the 10 MHz region are at a minimum.

4.6.5 Problem Areas

Searching for echoes is a difficult task and if one can be generated, the results are unpredictable and probably unrepeatable. This experiment should be given low priority. It could be done by studying sounder data from other experiments rather than making it a separate item requiring expensive orbital time.

4.7 RADIO FREQUENCY SOUNDER

4.7.1 Objectives

To provide a general research tool for studies of a wide variety of plasma-wave phenomena stimulated by RF waves transmitted from the Orbiter, and to provide real-time information on the state of the ionosphere both near and remote from Spacelab.

4.7.2 Proposed Methods

The plasma-wave studies would include four methods or areas of study. The first area would be to determine the perturbation threshhold level for a variety of wave to particle and wave to wave interactions which involve plasma wave instabilities and non-linear phenomena of interest to many astrophysical, geophysical, and laboratory plasma problems. For example, the solution to the puzzling problem of the acceleration mechanism for auroral zone particles will most likely require an understanding of such processes. The second area would determine how efficiently and under what conditions electromagnetic and electrostatic modes are coupled in a plasma. The conversion of electrostatic-to-electromagnetic is fundamental to astrophysical problems, because it enables evidence of plasma disturbances to be transmitted over long distances; e.g., the radio bursts associated with solar flares. This conversion is also of great interest in experiments involving the collisionless heating of a plasma; e.g., in experiments directed toward the achievement of controlled thermonuclear fusion. The third area would determine the distribution of the RF power output between electromagnetic and electrostatic wave modes and the kinetic energy of locally-accelerated charged particles. The fourth area would study the propagation of electromagnetic and electrostatic signals near characteristic frequencies of the ambient plasma. Such dispersion studies can be used to determine the ambient charged-particle densities and temperatures in a large volume around the Orbiter, thus minimizing the perturbing effect of Orbiter.

In addition to the diagnostic information obtained from the fourth area of study, the transmitter/receiver system on Orbiter would be able to operate in the conventional sounder mode with a real-time ionogram display available to the operator.

This experiment will utilize a flexible RF sounder, consisting basically of a transmitter and receiver on the pallet and antennas at the end of a 50-meter boom. Additional antennas on a separate boom and a receiver/antenna complex on a subsatellite would greatly enhance the system capability. The transmitter and receivers must have the capability of operating in the swept frequency and fixed frequency modes from 300 kHz to 30 MHz and must be programmable. The transmitter should have the following parameters as variables: peak pulse power (from 0 to 10 kW), pulse width (including CW operation in the lower power range), pulse repetition frequency, and pulse shape. In addition, it must have the capability to coordinate operation with other transmitters on the same vehicle (such as the one to be used with the VLF experiment). The sounder must have a computer for active control of programmable features of the transmitter and receiver and for frequency analysis of the received signal. Fluxgate magnetometers at the end of the boom containing the transmitting antenna will be used to orient the antenna with respect to the

magnetic field direction and a rhubidium vapor magnetometer, also at the end of the boom, will provide an output signal which can be used to control the transmitter frequency with respect to the ambient electron cyclotron frequency.

A real-time ionogram display is required for the sounder operation along with receiver versus time display. For plasma wave studies, a frequency spectrum of the received signal is needed. The sounder would be such that various antenna types and configurations can be used with minimal coupling problems.

4.7.3 Typical Instruments

The following table shows the instruments on the Orbiter and a Radio Frequency Subsatellite. The priority of each instrument is also shown.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
405	Radio Frequency Sounder	1
411	ELF/VLF Receiver	2
415	VLF Quadrupole Probe	3
418	VLF Antennas and Transmitters	2
548	Vector Magnetometers	1
	RADIO FREQUENCY SUBSATELLITE	
411	ELF/VLF Receiver	1
548	Vector Magnetometers	1

4.7.4 Orbit and Timeline Constraints

There should be no orbital constraints associated with the experiments described. Attitude may be critical for specific sections of this experiment, but in most cases, knowing the attitude within 1° to 3° accuracy is sufficient if the transmitting antenna is aligned perpendicular

to the earth radii. This experiment will probably interfere with most of the low-power RF instruments and allowance should be made in the time-line for this problem.

4.8 LOWER HYBRID RESONANCE EXPERIMENTS

4.8.1 Scientific Objectives

This experiment will study the propagation of VLF electrostatic and electromagnetic fields at frequencies near that of the lower hybrid resonance (LHR). Measurement of the radiation patterns of short electric dipoles at these frequencies will also be carried out with application of the results related to the development of an ac method for precise measurement of dc electric fields. A secondary objective will be the improvement of antenna design resulting from knowledge gained from this experiment.

4.8.2 Proposed Methods

Measurements are to be made of the near and far fields of a short dipole around the LHR. For near-field measurements, the sensor array comprises four spherical electrodes, each of 1 cm radius, placed at the 4 corners of a square having sides of roughly 4 m. The electrodes are connected so as to form 2 parallel dipoles, one of which is used for transmitting and the other for receiving. This can be done in four possible ways. This array is mounted on the end of a long (20 to 50 m) boom. A receiver is used to measure transfer impedance between dipoles as a function of frequency in the range 20 Hz to 20 kHz.

For the far-field measurements, an additional dipole is mounted on the end of a second long boom, and VLF signals are propagated between this antenna and the others. The length of the propagation path is varied (5 to 50 meters) by controlling the angle between the two booms, while its orientation with respect to the earth's magnetic field and to the orbital velocity vector is varied by use of the Orbiter reaction control system.

The effects of bulk plasma motion, due to perpendicular dc electric fields in the Orbiter coordinate frame, are revealed by reversing the direction of propagation for a given frequency, distance, and orientation.

4.8.3 Typical Instruments

The following instruments are planned for use on this experiment. The priority of each instrument is also shown.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
415	VLF Quadrupole Probe	1
537	Ion Mass and Distribution Analyzer	1
548	Vector Magnetometers	1

4.8.4 Orbit and Timeline Constraints

This experiment is not suitable for subsatellite installation. Missions with low inclination, ellipitical orbits at altitudes between 200 and 400 km will probably yield the most information. Orbiter attitude rates in pitch, roll, and yaw will have to be less than 0.1° per second. The instruments used for this experiment are highly EMI susceptible and allowances should be made for this when planning timelines.

4.9 PULSE PROPAGATION AND GROUP DELAY

4.9.1 Scientific Objectives

The objective of this experiment is to demonstrate the classical theory of pulse propagation in a dispersive medium as originally developed by Sommerfeld. The ionospheric parameters permit instrumentation for detailed observation of "delta-function" pulse propagation involving forerunners at the speed of light and successive wave-packets in transverse and longitudinal plasma wave modes.

4.9.2 Proposed Methods

Very short, high power, RF pulses (50-nanosecond pulse length, 1 kilojoule peak power) will be generated by instrument 421 and applied to a dipole antenna oriented parallel or perpendicular to the earth's

magnetic field. The (frequency) dispersed signals will be received by instrument 421 and by the RFSS (Radio Frequency Subsatellite). The RFSS would measure right and left hand polarized waves, langmuir waves or forerunners, ordinary and extraordinary modes, and cyclotron harmonic waves.

4.9.3 Typical Instruments

The following table shows the instruments to be carried on the Orbiter and RFSS. The priority of each instrument is also shown.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
421	Pulse Generator and Dispersion	1
527	Langmuir Probe	2
537	Ion Mass and Distribution Analyzer	2
548	Vector Magnetometer	1
	RADIO FREQUENCY SUBSATELLITE	
555	Dc Electric Field	1
548	Vector Magnetometer	-
411 or 416	ELF/VLF Receiver Six-Component Measurement of Randon VLF Wave Fields	1 1

4.9.4 Orbit and Timeline Constraints

This experiment would be performed in a nominal 400-km polar orbit to obtain a maximum variation in plasma parameters. The pulse generator will be a large power user, so it will be activated for brief periods at various points in the orbit.

4.9.5 Problem Areas

Much more analysis and modification of the requirements needs to go into this experiment before it can become a reality. The three major areas of concern are power, size, and coupling the output to an antenna. A 1-kilojoule pulse delivered in 50 ms is a peak power of 20 gigawatts. To achieve pulses of this level requires hardware, which would be too large for the Shuttle to carry. Also, coupling the pulse to a dipole antenna requires development.

4.10 PLASMA-NEUTRAL GAS INTERACTIONS ($V_{CRITICAL}$ PROBLEM)

4.10.1 Scientific Objectives

This experiment will seek a plasma-neutral interaction postulated by Alfven's theory of the origin of the solar system. A rapid ionization of a neutral cloud by a streaming plasma, in the presence of a transverse magnetic field, has been observed in the laboratory. A very rapid ionization and momentum exchange occurs when the kinetic energy due to streaming exceeds twice the ionization energy. It is important to repeat this experiment in the ionospheric plasma where the plasma density is 6 orders of magnitude lower than that of ground-based laboratories.

4.10.2 Proposed Methods

Neutral gas (in the form of vaporized heavy alkali metals) will be released in kilogram quantities as close to the Orbiter as practical (10 kilometers) on the nightside of the earth. A first observation will be to use optical instrumentation on the Orbiter to look for the light from the ionization. If this is successful, then on a subsequent release, optical, R.F., electric field and particle measurements will be carried out. In addition to these measurements, it would be highly desirable to have two (stereo) ground-based image intensifier cameras, synchronized by radio, look at the release area to obtain three-dimensional pictures.

4.10.3 Typical Instruments

The following table shows the instruments on the Orbiter and Particle Detector Subsatellite.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
116	Airglow Spectrograph	3
122	UV-VIS-NIR Spectrometer/ Photometer	2
405	Radio Frequency Sounder (Receiver)	2
411	ELF/VLF Receiver	2
534	Optical Band Imager and Photometer System	1
548	Vector Magnetometer	1
554	Chemical Release Module	1
	PARTICLE DETECTOR SUBSATELLITE	
121	Neutral Mass Spectrometer	2
526	Photoelectron/Secondary Electron Spectrometer	2
538S	Ion Mass and Distribution Analyzer	1
548	Vector Magnetometer	1
	EXPENDABLE FIELD PROBE(S)	
548	Vector Magnetometers	1
555	Dc Electric Field	1

4.10.4 Orbit and Timeline Constraints

This experiment must be performed on the dark side of the earth since materials with ionization potentials low enough for streaming excitation are readily photoionized. A polar orbit is desirable so that releases may be made with different transverse field components.

4.10.5 Problem Areas

The chief area of concern is the safe handling of pyrotechnics. Another area of concern is the use of Orbiter instrumentation which would allow smaller releases of material as compared with the larger releases required for visibility from ground-based instrumentation.

4.11 CREATION OF AN ARTIFICAL COMET

4.11.1 Scientific Objectives

This experiment will seek to create a comet-like object by release of an alkali metal plasma at a distance of approximately 25 earth radii. It will study plasma photoionization and interaction with the solar wind.

4.11.2 Proposed Methods

A 1000 kg barium thermite canister will be staged from the Orbiter or from the ground for a plasma release at an altitude of approximately 160,000 km. This event is expected to produce a 1000 km radius diamagnetic cavity within a time frame of roughly twenty minutes. The cavity should persist up to two hours. Rays and a general cometary appearance are predicted on theoretical grounds. The "comet" would be observed by optical means from both the Orbiter and ground observatories. Plasma and magnetic field diagnostics instruments will be deployed from the release module and make in-situ measurements at the release point.

4.11.3 Instruments Required

The following table shows the instruments on the Orbiter and their priority.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
116	Airglow Spectrograph	2
122	UV-VIS-NIR Spectrometer/ Photometer	1
124	Fabry-Perot Interferometer	3
129	Near IR Spectrometer	3
534	Optical Band Imager and Photometer System	1
554	Chemical Release Module	1
557	Booster firing capability	1

4.11.4 Orbit and Timeline Constraints

Detailed orbit and timeline constraints for optimum performance of this experiment have not been determined, however, orbital inclination and altitude of the Orbiter would not be critical.

4.11.5 Problem Areas

Safety restrictions may preclude carrying such a large thermite release on the Orbiter. However, the release could be boosted to orbit from the ground.

4.12 PLASMA FLOW INTERACTIONS WITH TARGET BODIES

4.12.1 Scientific Objectives

The objective of this experiment is to study the phenomena and the governing physical mechanisms involved in the interaction between a body and a flowing plasma. The information so obtained should yield a better understanding of the environments of satellites, moons, asteroids, planets, and comets.

4.12.2 Proposed Methods

A test body will be deployed from the Orbiter into the ambient plasma. The disturbed plasma flow around the body will be scanned with an array of particle and field diagnostics. In addition, the ambient (undisturbed) plasma will be measured with a separate set of diagnostics. Depending on specific experimental objectives, the test body will assume a variety of sizes and/or shapes and may have a conducting or non-conducting surface. A magnet with a controllable field should be located within the body. Depending upon the size of the test body, it may be boom-mounted on the Orbiter, or may be tethered, or a free flyer. The diagnostics for mapping the disturbed zone may be boom-mounted or on a maneuverable subsatellite. In any case, the diagnostics for diagnosing the undisturbed zone will probably be boom-mounted on the Orbiter.

4.12.3 Typical Instruments

The following table shows the instruments that will be boom-mounted on the Orbiter for diagnosing the undisturbed plasma. The priority of each instrument is also shown.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
121	Neutral Mass Spectrometer	1
526	Photoelectron/Secondary Electron Spectrometer	1
527	Langmuir Probe	1

Instrument no.	Instrument title	Instrument priority
	ORBITER	
530	High Frequency Quadrupole Probe	2
411	ELF/VLF Receiver	1
535	Dc Electric Field	1
537	Ion Mass and Distribution Analyzer	1
548	Vector Magnetometers	1

The following instrument may be either boom-mounted or tethered to the Orbiter, or may be a free flyer.

556 Target Bodies - 1

The following instruments for mapping the disturbed zone may either be mounted on a maneuverable boom attached to the Orbiter or on a maneuverable subsatellite:

526 Photoelectron/Secondary Electron Spectrometer - 1

527 Langmuir Probe - 1

538 Subsatellite Ion Mass and Distribution Analyzer - 1

548 Vector Magnetometers - 1

4.12.4 Orbit and Timeline Constraints

The preferred orbit is one of low inclination, but the experiment may also be performed equatorward of the auroral zones in high inclination orbits. The experiment should be performed at several different altitudes to obtain different plasma parameters.

4.13 SOUNDING OF THE SHUTTLE WAKE AND OF NATURAL INOSPHERIC IRREGULARITIES WITH BISTATIC DOPPLER TRACKING

4.13.1 Scientific Objectives

Using the Doppler tracking method, this experiment will measure the electron density distribution in the Orbiter wake and provide a means of investigating the electrodynamic/aerodynamic properties of the Orbiter in various attitudes in an unbounded magnetoplasma.

4.13.2 Proposed Methods

Repetitive probing of the Orbiter wake in several directions and up to distances where the medium is undisturbed will be carried out between the Orbiter and a subsatellite. The two frequencies (harmonically related) must be phase coherent. Due to plasma dispersity, the electron density distribution in the wake affects the phase velocity of the two waves in a characteristic way. By inverting these phase changes measured at any point of the subsatellite's trajectory, local values of the electron density along the propagation path through the wake can be deduced.

Faraday rotation between the two link's terminals provides the measurement of the total columnar electron content along the radio path. The same link, with the subsatellite connected to a longer tether or free-flying can also be used to measure the natural ionospheric density perturbations.

4.13.3 Typical Instruments

The following table shows the instruments on the Orbiter and their priority.

Instrument no.	Instrument title	Instrument priority
	ORBITER	
409	Doppler Tracking Bistatic Radar	1
548	Vector Magnetometer	1
535	Dc Electric Field	3
526	Photoelectron/Secondary Electron Spectrometer	2
527	Langmuir Probe	3

4.13.4 Orbit and Timeline Constraints

This experiment will have no orbital or timeline constraints as long as spacecraft attitudes can be maintained. Pitch, roll, and yaw rates have not been determined, but will be the major constraint. The experiment should be performed in the Earth's F-region at an altitude of 350 to 500 km.

4.13.5 Problem Areas

This experiment should be considered more of an engineering diagnostic than a scientific experiment. The free-flying subsatellite is preferred to the tethered one.

Rather than use a transponder on the subsatellite, a reflector should be seriously considered. It can do what is required and is less costly to build. The subsatellite will have to be inertially stabilized in either case because an antenna or a reflector would require stable orientation.

5.0 INSTRUMENT DESCRIPTIONS

This section contains descriptions of all but six of the remaining substitute instruments that have been defined but not described in Volume 1, 2, or 3. These six instruments that remain yet to be described are:

a. 424 - Microwave Limb Scanner

b. 421 - Group Velocity Measurements

c. 554 - Chemical Release Module

d. 557 - Booster Firing

e. 553 - EMF Generator

f. 556 - Targets Bodies

In addition, four of the satellites/subsatellites have not been completely defined or described and they are:

a. Radio Frequency Subsatellite

b. Throw Away Magnetometer

c. Electric Field Probe

d. Solar Satellite

5.1 NEUTRAL MASS SPECTROMETER - INSTRUMENT 121

5.1.1 Objective

The Neutral Mass Spectrometer will measure the concentration or density of the neutral molecules, atoms, and other free radicals with good spatial resolution and sensitivity. It is known that the density of the various chemical species changes considerably as the result of local heating and other effects. By determining the concentrations quantitatively and combining these data with information about the perturbing effects, an improved understanding of the atmosphere will be obtained.

A feature of this mass spectrometer, compared to previous mass spectrometers, will be the addition of a retarding grid (to be described later) to reject the thermalized component of the ion source density. This component will come to chemical and thermal equilibrium on the walls; for example, the atoms will combine. Among other capabilities, the retarding potential analyzer (RPA) will permit the measurement of the ambient O_2 and NO by measuring the gases before the recombination of atoms occurs. The retarding grid also will have the advantage of rejecting molecules in thermal equilibrium with the vehicle and those outside a narrow acceptance cone; thus, permitting its use on the Orbiter despite significant outgassing and contamination. Modes with and without the retarding potential will be used.

Although it is feasible to perform the functions of this instrument with certain modes of the neutral temperature and wind spectrometer, it will be highly undesirable, because measurements of both composition and velocity will be required simultaneously.

5.1.2 General Description

5.1.2.1 Location.- This instrument will be mounted on a boom.

5.1.2.2 Configuration.- Prior to launch, the sensor will be evacuated. After the pressure of the environment becomes sufficiently low for operation, a pyrotechnic charge will fracture a ceramic annular enclosure at the entrance. Afterwards, a sector cover may be swung over the instrument for protection against contamination.

The ambient molecules will enter a 4-cm diameter spherical antechamber via a knife edged 3-1/2-mm diameter circular orifice. Molecules entering at exactly right angles to the aperture will go straight into the ion chamber without colliding with the antechamber. Those entering at a significant angle will bounce around in the antechamber and attain thermal equilibrium before entering the ion chamber. Equilibrium will include the recombination of atoms. The factors which will govern the ratio of the density of the gas in the chamber to the density of the gas outside are well known; thus, the external density can be calculated from the measured density in the chamber. See figure 5-1 for the overall concept.

The gas will travel from the antechamber to the ion chamber where it will be ionized by a focused electron beam emanating from a 0.15-mm tungsten-rhenium filament. The electrons will be accelerated to 90 eV, drift across the ionizing region, and collected at the anode.

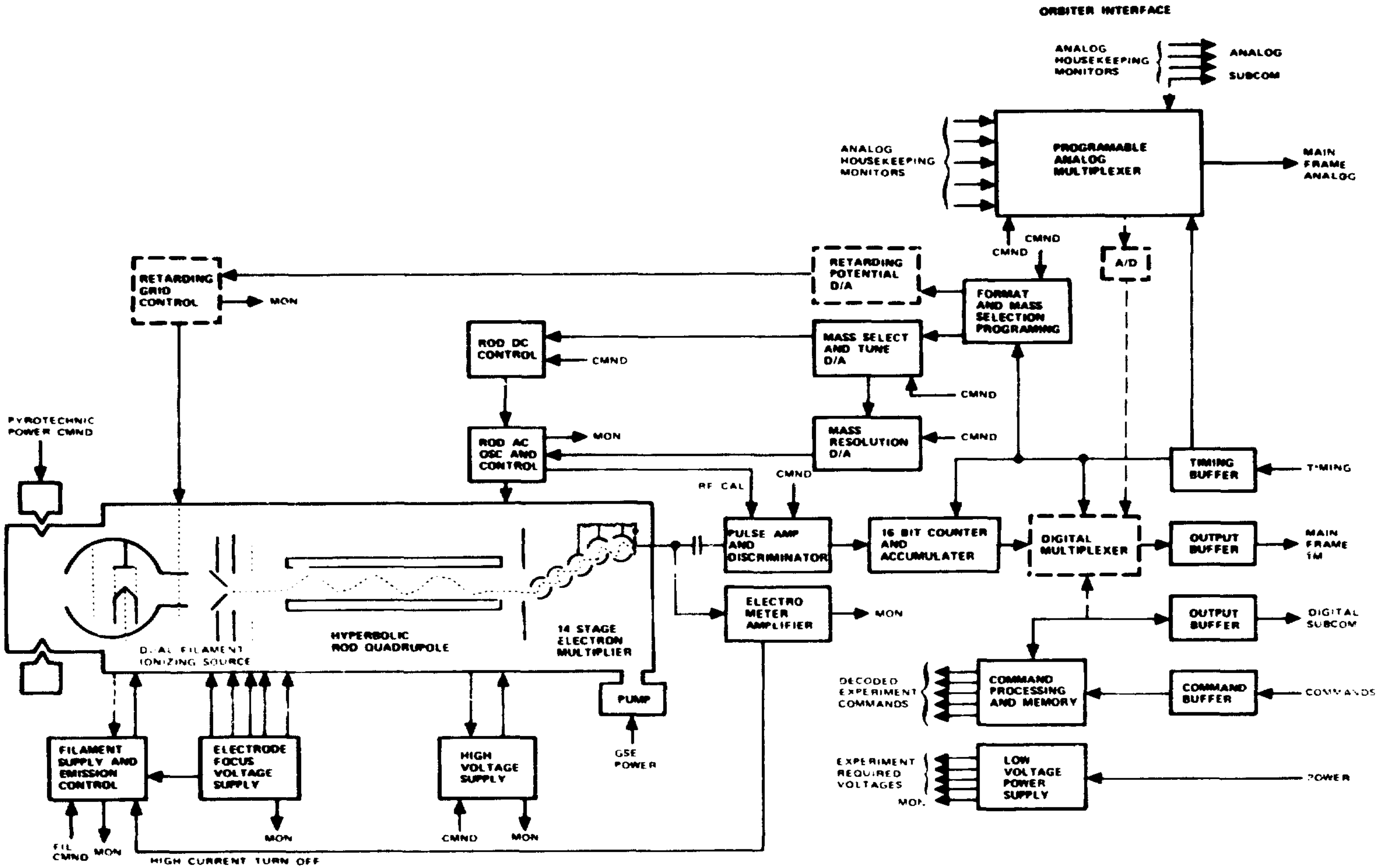


Figure 5-1.- Neutral Mass Spectrometer.

A small fraction (1 in 10^5) of the neutrals in the ion source will be ionized by electron impact. Two redundant hot filament electron sources will be used, and a variable ionizing energy will be achieved by selecting the filament potential with respect to other electrodes of the electron guns. A constant ionizing current will be maintained by controlling electrode potentials with a feedback regulator. One of five different ionization currents will be used, depending upon the density range required. The current will be automatically selected according to the output signal.

Ions created in the source will be introduced into the analyzer through the retarding grid assembly. The RPA will be operated in one of three modes: (1) a zero retarding field where ions of all energies will be accepted, (2) a fixed retarding field of finite value to reject the thermalized component, and (3) a swept potential to perform the retarding analysis for any selectable mass. It is assumed that ionization will not change the kinetic energy of the molecule and that multiple ionization can be neglected.

Ions which overcome the field of the retarding grid will be focused and accelerated into the quadrupole analyzer. In the analyzer, the ions will be decelerated and separated in terms of a mass-to-charge ratio in the combination ac and dc electric fields. The four parallel analyzer rods will be 15-cm long with hyperbolic surfaces. The ions will oscillate between them with a complicated pattern. Only ions with the specific mass-to-charge ratio, for which the instrument is tuned, will pass through. The others will go out the sides.

Ions will exit the quadrupole analyzer through a weak focusing lens and will be accelerated into an electron multiplier. As the ions enter the multiplier aperture, they will be turned 90° to strike the first dynode of a 14-stage off-axis beryllium copper diode multiplier operating at a gain of roughly 2×10^6. The multiplier will provide an output pulse of electrons for each ion arrival. The off-axis multiplier will eliminate several deleterious background contributions, e.g., charge exchange neutrals. The multiplier output pulses will constitute the measurement, and the count rate will be proportional to the chamber density of the selected (tuned) gas.

The instrument will be located on a boom on the forward part of the vehicle with 2π sr clear field of view in the forward direction. One instrument will be located on the Orbiter and one on a satellite. The satellite location will give added assurance against contamination, while the Orbiter location will permit measurements of both contaminants with mass under 46 and the ambient atmosphere.

5.1.2.3 Specifications.- The various specifications applicable to this instrument are shown in the following subparagraphs.

5.1.2.3.1 Ranges: The mass numbers measured will be from 1 to 45, and the dynamic range must be greater than 10^7.

5.1.2.3.2 Resolution: Two different species of molecules separated by one mass unit can both be detected even when one is measured 10^{-4} lower than the concentration of the other. The spatial resolution will be 128 m along the flight path and the temporal resolution 16×10^{-3} sec.

5.1.2.3.3 Sensitivity: The minimum detectable concentration will vary greatly with the type of gas molecule; however, the typical noise equivalent concentration will be 5×10^3/cu m. This will give a 5 per-cent error at a concentration of 10^5/cu m. The sensitivity will set the upper altitude limit for detecting O_2 at 250 km, Ar at 300 km, N_2 at 550 km, O at 700 km, and He at 1000 km, although measurements will be made best in the 200 to 400 km range.

5.1.2.3.4 Field of view: The field of view will be 2π sr, except for the retarding potential mode which will have a 5° field of view. The molecules entering from any infinitesimal solid angle will be weighted in the output signal according to the cosine of the angle between the entering line and the normal to the aperture.

5.1.2.3.5 Data collection rate: This rate will be one sample every 16×10^{-3} sec.

5.1.2.3.6 Power: 28 Vdc, 12 W average and maximum

5.1.2.3.7 Physical dimensions: The size of the sensor package is 23.5 cm high, 13.1 cm wide, and 17.8 cm long and the electronics package with logic is 14 cm high, 10 cm wide, and 25 cm long. The total weight of both packages is 10 kg.

5.1.3 Operation

5.1.3.1 Pointing Requirements.- The pointing accuracy will be within 2° of forward motion.

5.1.3.2 Stabilization and tracking requirements.- No angular rate limitation will exist. The attitude must be known to 0.1° for using the retarding potential; otherwise, it will be 2°.

5.1.3.3 Timeline.- After the gas density outside has become sufficiently low, resulting from the falling off of vehicle outgassing, the explosive release will be activated upon command to break the seal.

After the surfaces have come to equilibrium (adsorption and desorption), the instrument will be activated. Complete warmup time will be 25 minutes; but after 10 minutes, corrections for incomplete warmup may be made from the output of the thermistor at the antechamber.

A choice will be made among five sequences of selection of mass number. The choices are:

Sequence	Mass Selection, amu
Geophysical	1, 2, 4, total, 16, 28, 32, selected, 40
Analytical	12, 14, 18, 20, 22, 30, 44, calibrate, 0
Individual	Selected, selected, selected, ... (any mass 1 to 45 amu)
Sweep-digital	1, 2, 3, 4, 5 . . . , 45 (in 3/16 amu steps)
Sweep-analog	2, 3, 4, 5, 6 . . . , 45 (continuous)

In addition, the tuning (sharpness of mass peak) with eight choices, ion current (sensitivity or dynamic range) with five choices, and mode for retarding potential will be selected.

5.1.3.4 Constraints.- Any obstruction of the 2π sr field of view will be undesirable. However, the retarding potential mode will have a narrow field of view, and the mode without the RPA will have the primary purpose of measuring contamination. Thus, no justification will exist for leaving the instrument off the Orbiter because of contamination. No operation will exist at pressures higher than 10^{-4} torr. It will be nonlinear above that point, but real trouble will not occur until 10^{-3} torr. The filament life will be 4 torr/sec.

If the pressure becomes too high, the instrument will shut off automatically and will require a command to reactivate. The thermal specifications of a previous design were: -40° to +40° C and for storage -40° to +60° C; however, the actual temperature limitations will be less restricting and determined by the electronics, not the sensor.

5.1.4 Checkout and Test

5.1.4.1 Boresighting requirements.- The boresight accuracy must be sufficient to determine the pointing direction to 0.1°.

5.1.4.2 Prelaunch checkout.- The prelaunch checkout will probably use ground support equipment built for the Atmosphere Explorer satellites, in which a similar mass spectrometer was used.

5.1.4.3 Preflight calibration.- The response to various gases will be measured by letting them enter the system through controlled small leaks for laboratory calibration. This may not be feasible for preflight because of the vacuum required.

5.1.4.4 Inflight calibration.- The instrument will be partly self-calibrating, because individual molecules will be detected, although the detection efficiency can be affected by contamination of the surfaces. Various gases will be leaked into the system to determine the response. If the gain of the electron multiplier has fallen off, then, for example, the pulses will become weaker, and the multiplier voltage will be increased. The output for zero level input will be measured by shutting off the ion current to the multiplier. This will usually be less than 1 count/sec except in radiation belts and in the South Atlantic Anomaly. The threshold of the system will be checked by sweeping the RP amplitude from zero to maximum.

5.1.5 Controls

a. Two pair of relay (major mode) commands

b. One 32-bit (minor mode) command

The above controls will include manual overrides.

5.1.6 Displays

A scope display of the mass spectra will exist with mass number markers or sample number, depending upon the choice of sequence; however,

this is not critical. Also, the mass number (3-bit word) and count (8-bit word) displayed digitally for one mass number will be desirable.

5.1.7 Data

a. Sixty-four 16-bit words/sec (scientific data) (four pairs of 8-bit words/mainframe at 16 frames/sec)

b. Sixteen 8-bit words/sec (digital housekeeping) (one 8-bit mainframe word)

c. Sixteen analog words/sec (analog housekeeping) (one, analog mainframe word)

d. Ten subcommutated analog words per 8 second

e. Four subcommutated 8-bit words per 8 second

The housekeeping data will include temperatures of the ion source and antechamber and electron currents to the accelerator, ion repeller and anode electrodes in the ion source.

5.1.8 Development Status

5.1.8.1 Forerunner instruments.- Nearly identical instruments, except for RPA, have been flown or will be flown on Atmosphere Explorers C, D, and E.

5.1.8.2 Problems.- Some operational problems are foreseen in that the requirements for 0.1° attitude information, the Orbiter location information to 100 m (this can be relaxed, if it is not feasible), and 2π sr clear field of view will be severe requirements. The time required to reduce the pressure due to the outgassing of the vehicle, the time required for chemical equilibrium of the surfaces of the instrument, and the contamination may cause problems.

5.2 NEUTRAL TEMPERATURE AND WIND (DRIFT) SPECTROMETER - INSTRUMENT 125

5.2.1 Objective

The Neutral Temperature and Wind (Drift) Spectrometer will measure both the temperature of the various constituents of the neutral atmosphere, especially nitrogen, which is most abundant, and the three orthogonal components of the ambient velocity of the neutral atmosphere.

The temperature will be obtained by placing a narrow rectangular baffle in front of the orifice of a mass spectrometer which will face forward, so as to partially block the flow into the orifice. Flow will occur around both sides of the baffle. With the baffle in a position of maximum blockage, the flow into the orifice will be a function of temperature, because an increase in temperature will increase the number of molecules flowing around the baffle and arriving at the aperture. When the baffle is at one side, the flow into the aperture will be only slightly dependent upon the temperature. The mass spectrometer's output will be proportional to the number of molecules entering the aperture. Thus, the temperature will be found from the shape of the curve of the mass spectrometer output versus the baffle position.

Information about the direction of the wind (nonrandom or uniform velocity) will be determined by the location of the baffle for minimum instrument response. The measuring technique will be similar to the method of determining the direction of an infrared radiation source by finding the location of a small object in the beam which causes the maximum shadowing of a detector. The Orbiter will travel at high velocity, so the molecules will always be coming in at the same general direction. Significant changes in the wind direction will appear as small changes in the apparent direction of the molecules at the Oribter. Two baffles at right angles will scan so as to give two-dimensional information; i.e., the transverse components of the motion. The longitudinal component of the velocity will be found as follows. As the gas comes in, it will be ionized by a crosscurrent without changing the velocity of the particles too much to affect the measurement. A retarding potential (RP) will block all ions with less than a certain velocity from entering the analyzer. The velocity distribution in the longitudinal direction will be found from the graph of output signal versus RP. These measurements will be made with the mass spectrometer set to detect molecules with the mass number kept constant.

5.2.2 General Description

5.2.2.1 Location.- This instrument will be mounted on a boom.

5.2.2.2 Configuration.- Two scanning rectangular baffles will be located in front at right angles to each other. Their size will be 3 x 1 cm. The sweep angle will be ±25°. The baffles will scan alternately.

The aperture will be a 0.5-cm diameter precisely edged orifice. It will open to a 3-cm diameter spherical sampling chamber. The relationship between the gas density inside the chamber and outside will be a function of geometry and will be known. The gas will reach an equilibrium concentration in the chamber except for the molecules entering the orifice at an angle near the normal and traveling to the ion chamber without striking the walls of the sampling chamber. When RP is not used, all the molecules entering the ionization chamber may be ionized and detected. However, when the RP is used, only the molecules impinging at right angles to the baffles and going straight through to the ionizing source will have sufficient energy to overcome the RP.

Because contamination on the walls of the chamber can cause adsorption or outgassing, the unit will be sealed under vacuum before launch. An explosive charge, upon command, will open the seal to prevent blockage of the aperture in space. Afterwards, a cover will protect the instrument from contamination when the instrument is not being used. The chamber will be vented on the side to permit gas passing through the chamber and being replaced.

The gas will go from the first chamber to the ionization chamber where a small fraction of the gas will be ionized by an electron beam at 90 V. The electrons will come from a heated filament outside the ion chamber but in a region connected to the chamber. The current may have one of five different values, in steps of factors of 2.5 to cover the various atmosphere density ranges.

The ions will go from the ion source via an orifice into the quadrupole analyzer, pulled by an electric field. However, at this point, an extra electrode with a controllable positive voltage (the RP) will keep ions which have kinetic energies less than an amount determined by the applied potential out of the analyzer. This potential may be varied to keep out ions with thermal energies, i.e., ions which have come in contact with the walls and lost their original energy. Thus, the quantity measured when the RP is used will be the density of external molecules with velocities along the axis of the instrument greater than a certain amount.

The analyzer will consist of four quadrupole rods, with a hyperbolic cross section to which ac and dc fields will be applied. As the ions oscillate in the fields in a complicated pattern, a resonance phenomenon will occur which will permit only ions with a certain mass-to-charge ratio to impinge upon the detector. The other ions will go out the sides. The mass number detected will be controlled by the ac voltages.

The detector will be a 14-stage electron multiplier.

The instrument will be most frequently tuned for molecular nitrogen with the mass 28, because it usually has the highest concentration. Thus, the temperature and uniform velocity of nitrogen will be measured. Other molecules will be selected as desired, especially O_2, by adjusting the ac voltages so their motion can be determined.

The instrument will be mounted forward and will face forward to receive the incoming gas without blockage by any structure. It may be mounted on a boom or subsatellite. Its readings will be less susceptible to interference than those instruments detecting charged particles.

5.2.2.3 Specifications.- The various specifications applicable to this instrument are shown in the following subparagraphs.

5.2.2.3.1 Ranges: The altitude ranges will be 130 to 500 km for 5-percent error in the measurement of the number of particles; statistics will set the upper limit, and the end of free molecular flow will set the lower limit. The heaviest molecule to be measured will be CO_2; i.e., the maximum mass number will be 44. Five different sensitivity ranges will exist which will be obtained by adjusting the ionizing current which changes in steps by the factor of 2.5.

5.2.2.3.2 Resolution: At maximum resolution, where two gases have weights separated by one mass number, a concentration of one as low as 10^{-4} times the concentration of the other can be detected. The actual resolution of the measured quantity will depend upon the altitude.

5.2.2.3.3 Sensitivity: See subparagraph 4.2.2.3.1.

5.2.2.3.4 Field of view: The field of view will be 2π sr when not using the RP mode; about 5° wide when using RP.

5.2.2.3.5 Data collection rate: The pulses of individual ions will be detected. The number of pulses will be integrated for 15 ms. The range of the number of ions per sec which can be counted will be 0 to 6×10^5.

5.2.2.3.6 Power: The power will be 13 W average, 14 W maximum, and no standby mode will exist.

5.2.2.3.7 Physical dimensions: The size of the instrument will be 0.25 x 0.25 x 0.25m, and the weight will be 9 kg.

5.2.3 Operation

5.2.3.1 Pointing requirements.- The pointing accuracy of the instrument must be within ±2°. The instrument's pointing direction must be known within 0.1°. This accuracy will be required, because it will be necessary to subtract the components of the spacecraft velocity from the components of the measured relative velocity of the gas to calculate the absolute velocity of the gas.

5.2.3.2 Stabilization.- The maximum angular rate will be 0.05 deg/sec.

5.2.3.3 Timeline.- When the vehicle is at altitude and after it has outgassed sufficiently, the cover will be removed and the pyrotechnic charge fired, thus opening the evacuated instrument to the outside environment, after which the instrument will be activated.

Warmup time will be one-half hour. The data-taking sequency will be as follows:

Time Duration, sec	Action
0.5	Verticle baffle traverses to the right.
0.25	Retarding potential is varied.
1.25	Horizontal baffle is moved up.
0.5	Vertical baffle is moved to the left.
0.25	RP is varied.
1.25	Horizontal baffle is moved down.

The motions of the baffles will be continuous. The RP will be a step function.

If the output signal is too low, due to a low density, the ion current will be automatically increased and, thereby, the signal increased (unless it is already on the most sensitive range).

5.2.3.4 Constraints.- Data cannot be taken until after the outgassing of the vehicle has been completed. The maximum operating pressure will be 10^{-5} mm Hg.

5.2.4 Checkout and Test

5.2.4.1 Boresighting requirements.- The instrument will be boresighted with the attitude measuring equipment of the vehicle; thus, the direction at which the instrument will later be pointed during data taking can be measured with an overall error of less than 0.1°.

5.2.4.2 Prelaunch checkout.- The interior of the instrument will be under vacuum at prelaunch. However, sufficient molecules will be present to operate the instrument as a test. In addition, checks of the electronics will be made.

5.2.4.3 Preflight calibration.- Preflight calibration cannot be performed because it would involve leaking gases into the system, which would destroy the vacuum for the sealed unit.

5.2.4.4 Inflight calibration.- The instrument will be essentially self-calibrating, because only relative values will be necessary for measuring the temperature (analogous to measuring the line width of an absorption spectrum). Calibrating with a known gas in flight will be impractical at the present state-of-the-art and not critical for the data.

5.2.5 Controls

The commands will be the pyrotechnic release, door open/close, power on/off commands, ion current selection (five values), and mode of mass selection (six modes). The latter will include staying at one mass number, especially that of N_2, or sequences involving various combinations of mass numbers.

The controls will be two pairs of relay commands, which will control the power and two 32-bit mode commands.

5.2.6 Displays

No strong requirements for any displays will exist.

5.2.7 Data

The following table presents the outputs.

Parameter	Type[1]	Amplitude	Word length, bits	Sample rate, sps	Bit rate
Spectrometer output	D		16	64	1024
Baffle position or retarding potential	D		8	16	128
Experiment commutator	A	0 to 5	8	16	128
Analog subcommuted	A	0 to 5	8	10/8	10
Command status	D		48	1/8	6

Note 1: A = analog; D = digital.

5.2.8 Development Status

5.2.8.1 Forerunner instruments.- A similar instrument without the baffles and RP has been flown on the Atmospheric Explorer (AE) satellite series. These refinements were not needed because the AE had a spin stabilized mode, and by taking data at all directions with respect to the forward velocity, all the components were obtained. Last year, a similar instrument was flown on AE-D with the improvement of adding the RP mode. The next logical step will be to add the baffles.

5.2.8.2 Problems.- No design or manufacturing problems are anticipated. However, in the operational sense, contamination can affect the operation. An excessive amount of time may be required for the vehicle to outgas before opening the chamber and time required for the chamber walls to come to chemical equilibrium (adsorption and desorption) with the ambient atmosphere.

5.3 NEAR INFRARED SPECTROMETER - INSTRUMENT 129

5.3.1 Objective

The Near Infrared Spectrometer will measure absorption spectra in the infrared spectrum from a (nominal) 1 to 5 micrometer wavelegth (10^4 - 2 x 10^3 cm^{-1}) at very high resolution (0.01 cm^{-1}). The principal mode of operation will be to use the sun as a source, looking through the earth's atmosphere at (horizon) altitudes of 10 to 100 km. A secondary, lower resolution mode will use reflected sunlight and earth emissions in a vertical view through the atmosphere.

5.3.2 General Description

5.3.2.1 Location.- This instrument will be pallet mounted.

5.3.2.2 Configuration.- The Near Infrared Spectrometer will be a rapid-scan Michelson-type interferometer with several novel features imposed by the short data-collection period available in solar occultations. The instrument will consist of external optics, the interferometer and detectors, a cryogenic cooler, a solar tracker, pointing mount, controls, displays, and a data handling system. An inflight calibration system will be provided.

The interferometer will be of the fast scan (continuously varying optical retardation) type with auxiliary white light and laser reference interferometers. A 3-element detector array will be used to obtain three separate interferograms of different portions of the occulted air column from each scan of the interferometer mirror. The interferometer will collect asymmetric interferograms (the white-light fringes will be at an end of the record rather than centered in the data). A low-resolution (1 cm^{-1}) pilot reduction of the data will be used to determine asymmetric phase corrections to the main spectrum.

The detector choice is still to be determined. Cooled photoconductive and pyroelectric detectors are possible candidates; cooling requirements will depend upon the choice of detector.

Instrument pointing will be slaved to a sun tracker which will acquire and hold the solar disk.

5.3.2.3 <u>Specifications</u>.- The specifications for this instrument are contained in the following paragraphs:

5.3.2.3.1 Physical measurements:

Spectral range	- (TBD), nominally 1 to 5 micrometers
Resolution	- 0.01 cm^{-1} spectral resolution 3 km spatial resolution
Sensitivity	- (TBD)
Field of view	- 0.1 degree nominal per detector element
Data collection rate	- (a) Occultation mode: approximately 40 interferograms of 10^6 samples each during 1 minute solar occultation (sample = 16-bit data word) (b) Earth viewing mode: (TBD)
Power	- (a) Tracker - 110V 400 Hz 10 w 28 VDC 14 w (b) Interferometer - 28 VDC 56 w (c) Display - 116V 400 Hz 200 w 28 VDC 84 w (d) Cryogen System - 28 VDC 140 w (e) Data System - (TBD)

5.3.2.3.2 Physical dimensions:

Size	- (a) Interferometer 0.5 m high x 10.0 m wide x 1.0 m deep: 0.5 m^3 volume (b) Controls and display 0.5 m high x 0.5 m wide x 0.5 m deep; 0.125 m^3 volume

(c) Cryogen system
0.2 m high x 0.2 m wide x 0.4 m deep; $0.016\ m^3$ volume

(d) Data handling system - (TBD)

Weight - (a) Interferometer - 50 kg

(b) Controls and display - 100 kg

(c) Cryogen system - 10 kg

(d) Data handling system - 50 kg

5.3.2.3.3 Other: The specifications are estimated on the basis of preliminary information and use in occultation; requirements for earth viewing have not been considered in detail.

5.3.2.3.4 Housekeeping: Housekeeping data to be interwoven in the scientific stream will include spacecraft altitude, instrument-mount gimbal angles, spacecraft time, detector biasing, scan rate and up to ten internal instrument temperatures.

5.3.3 Operation

5.3.3.1 Pointing requirements.- The instrument must remain stable within ±0.03 degree RMS during a 3-second interferogram collection period during occultation. Pointing requirements for earth viewing are to be determined.

5.3.3.2 Timeline.- Occultations occur at spacecraft sunrise and sunset. The period of occultation is approximately 1 minute in orbits included in the ecliptic (duration of the event is inversely proportional to spacecraft altitude). Occultation in polar orbit will be longer, but will yield measurements of slanted air columns which are less desirable. The instrument will acquire the sun before there is significant absorption in the line of sight and commence taking calibration data. At approximately 200-km terminator altitude, there will be a sharp rise in ultraviolet absorption, detectable by the sun tracker which can be used to alert the operator to an eminent occultation or initiate a preprogrammed operational sequence. Data acquisition will cease when the sun is obscured by the earth. Altitude information will be recovered in post-processing based on IRIG time and spacecraft ephemeris data (sunset occultations). Sunrise occultations will essentially reverse the order of operation.

Earth-viewing measurement timelines have not been considered in detail; however, it will be necessary to conduct operations on the sunlit side of the earth.

5.3.4 Constraints

The Near Infrared Spectrometer will be a very high data output device when used in the occultation mode, but with a small-percentage duty cycle. Other high data-rate instruments may be adversely impacted by operation of this instrument. The question of direct recording of the data stream versus buffering with a slow readout has not been resolved.

5.3.5 Checkout and Test

5.3.5.1 Boresighting requirements.- The instrument will be boresighted with reference to the spacecraft axes to 0.1 degree.

5.3.5.2 Prelaunch checkout.- A GSE (ground support equipment) test set will provide exercising signals to verify operation of the electronic components and systems.

5.3.5.3 Preflight calibration.- The instrument will be ground checked by sun tracking exercises and GSE sources.

5.3.5.4 Inflight calibration.- Primary inflight calibrations will be accomplished using the sun as a source. Integral blackbody as lamp sources are desirable, but will be of much lower intensity then the sun.

5.3.5 Control

Control Requirements have been identified for the following items:

Instrument aiming	Two axis slew and fine pointing, slaving to suntracker or external guidance.
Instrument alignment	Two axis tilt adjustment on at least one interferometer mirror, optical focus adjustment. Two axis detector array positioning.

Operating mode	On/off/standby, instrument doors and covers, scan rate, display of white light, reference, and data interferograms, data record, and preprogrammed data acquisition cycles select.
Operating parameters	Detector bias, amplifier gains, detector temperature and instrument heaters
Calibration sources	To be determined

5.3.6 Display

The instrument operator will require display of all controlled parameters or command status. Cathode Ray Tube (CRT) displays will be required for interferograms and truncated spectra used in aligning the instrument.

5.3.7 Scientific Data

The scientific data will be 16-bit digital words in a yet to be determined format which will interleave the data interferogram information from each of the detectors, white light, and reference interferograms and housekeeping data. The estimated data stream will be twice the one million word per second data stream of the main detectors or 32 megabits/second.

5.3.8 Development Status

Rapid-scan Michelson interferometers of lower resolution and data rate are available as laboratory instruments from a number of manufacturers. The first use of Michelson interferometers in space was the Infrared Interferometer Spectrometer (IRIS) carried on Nimbus 3 in 1969.

5.3.9 Problems

5.3.9.1 Design and manufacture.- The spread of capabilities between commercially available instruments and the specifications for the Near Infrared Spectrometer is very large. Design and fabrication of this instrument will be a major undertaking.

5.3.9.2 Operational.- The very high data rate of this instrument may require a dedicated recording system or preclude the use of other high data rate instruments when the Near Infrared Spectrometer is used.

Displays, controls and data systems will be shared with Instrument 126, the cryogenically-cooled interferometer spectrometer, precluding simultaneous use of the two instruments.

5.4 ION ACCELERATOR - INSTRUMENT 301

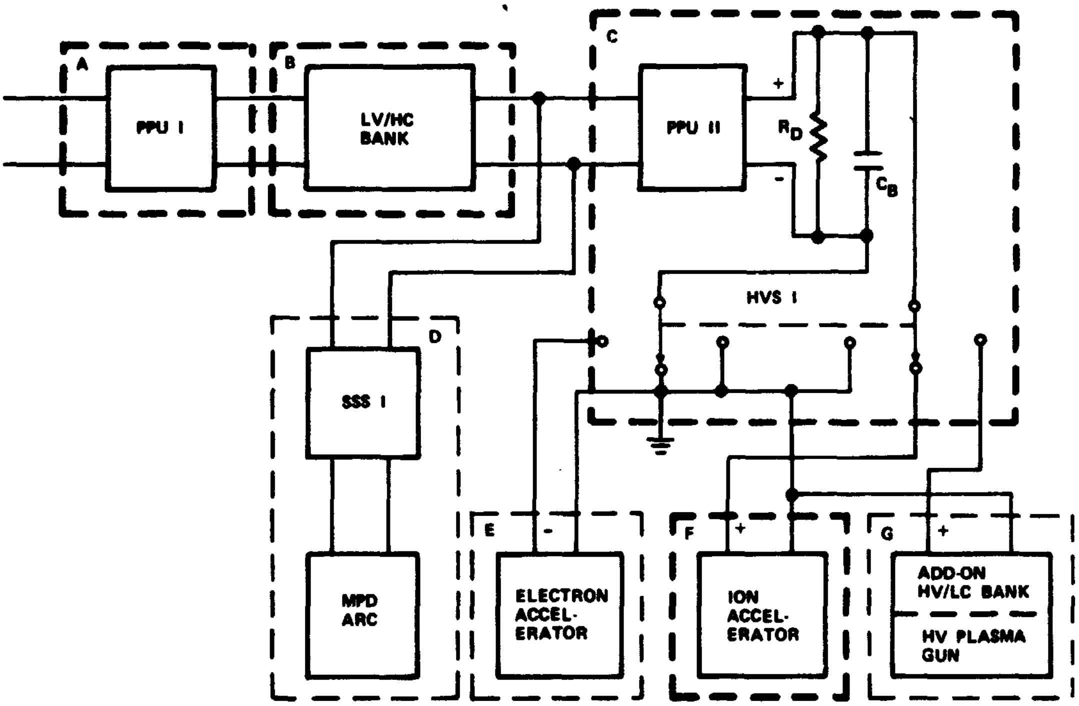
5.4.1 Objective

The Ion Accelerator will be used (1) to study the excitation of neutral components of the atmosphere, (2) to study the excitation of plasma components in the ionosphere, (3) to map magnetic field lines of the earth, (4) to determine the magnitudes and directions of ionospheric electric fields, and (5) for the excitation of plasma waves in the ionosphere.

5.4.2 General Description

5.4.2.1 Location.- This instrument will be mounted on the pallet.

5.4.2.2 Configuration.- The Ion Accelerator will be a subsystem of the AMPS Particle Accelerator System (see figure 5-2). In this system, 28 Vdc power will be from the Orbiter converted to 500 Vdc by subsystem A and stored in a capacitor bank (subsystem B) for high-intensity pulsed operation. Subsystem B will feed a voltage converter (subsystem C) which will be capable of a voltage output up to 30 kV. The Ion Accelerator proper (subsystem F) can be connected to the 30 kV output when its operation is desired. The Ion Accelerator will be composed of a chamber into which gas (of the ion species desired) will be fed. By means of a bombardment voltage placed across suitable electrodes, a high-intensity discharge will be initiated in the gas. The accelerating voltage from subsystem C will be placed across the chamber, and an extraction electrode will accelerate the ions to the desired energy and output them in a beam. A second gas system will feed gas to a set of electrodes external to the accelerator. Here, a small plasma will be set up to provide a supply of ions for a return current to the accelerator, to neutralize voltage build-up on the accelerator produced by the primary ion beam. The Ion Accelerator will be used in conjunction with an assortment of particle detectors, wave receivers, ion probes, and spectrophotometric instruments both for diagnostics of the beam characteristics in the vicinity of the accelerator and for the sensing of remote phenomena generated by the ion beam.



SUBSYSTEM	ELEMENTS
A	POWER PROCESSING UNIT (PPU) I (28V/400A/ /500V/23A)
B	LOW VOLTAGE/HIGH CAPACITANCE (LV/HC) BANK (500V/0.8F)
C	PPU II (500V/400A/ /30,000V/10A), DRAINAGE RESISTOR (R_D), BUFFER CAPACITOR (C_B), HIGH VOLTAGE SWITCH (HVS) I
D	SOLID STATE SWITCH (SSS)1, MAGNETOPLASMADYNAMIC (MPD) ARC (500V/200,000A)
E	ELECTRON ACCELERATOR (30,000V/7A)
F	ION ACCELERATOR (20,000V/10A)
G	ADD-ON HIGH VOLTAGE/LOW CAPACITANCE (HV/LC) BANK, HIGH VOLTAGE (HV) PLASMA GUN

Figure 5-2.- AMPS Particle Accelerator System.

5.4.2.3 Specifications.- The following subparagraphs contain the specifications applicable to this experiment instrument.

5.4.2.3.1 Beam Characteristics: The beam energy will have a range of 1 to 20 keV with a beam energy spread ($\Delta E/E$) that is less than or equal to 0.1. The beam current will be 0 to 10A. The beam angular divergence will be $\pm 6°$ maximum.

5.4.2.3.2 Operating modes: The operating modes for this experiment will be direct current (dc) and pulsed. The repetition rate and pulse duration will be variable with 0.05 duty cycle at maximum power output. The minimum pulse width will be of the order of 10 ms and the maximum pulse rate will be on the order of 10/sec.

5.4.2.3.3 Pitch angle variability: The pitch angle variability is 0° to 180° (by vehicle orientation).

5.4.2.3.4 Gas (Ion) species: Hydrogen initially will be recognized with other gases possible in a growth mode.

5.4.2.3.5 Power input: The power input to the instrument will be 28 Vdc with a standby power usage of 50 W. The average power usage will be 5 kW and maximum power usage will be 10 kW. Energy storage for the high intensity pulses will be accomplished by means of a 10^5 J, 0.8 F, 500 V capacitor bank.

5.4.2.3.7 Physical dimensions: The physical dimensions of the Ion Accelerator and its associated driving system and gas supply are shown in figures 5-3, 5-4, and 5-5.

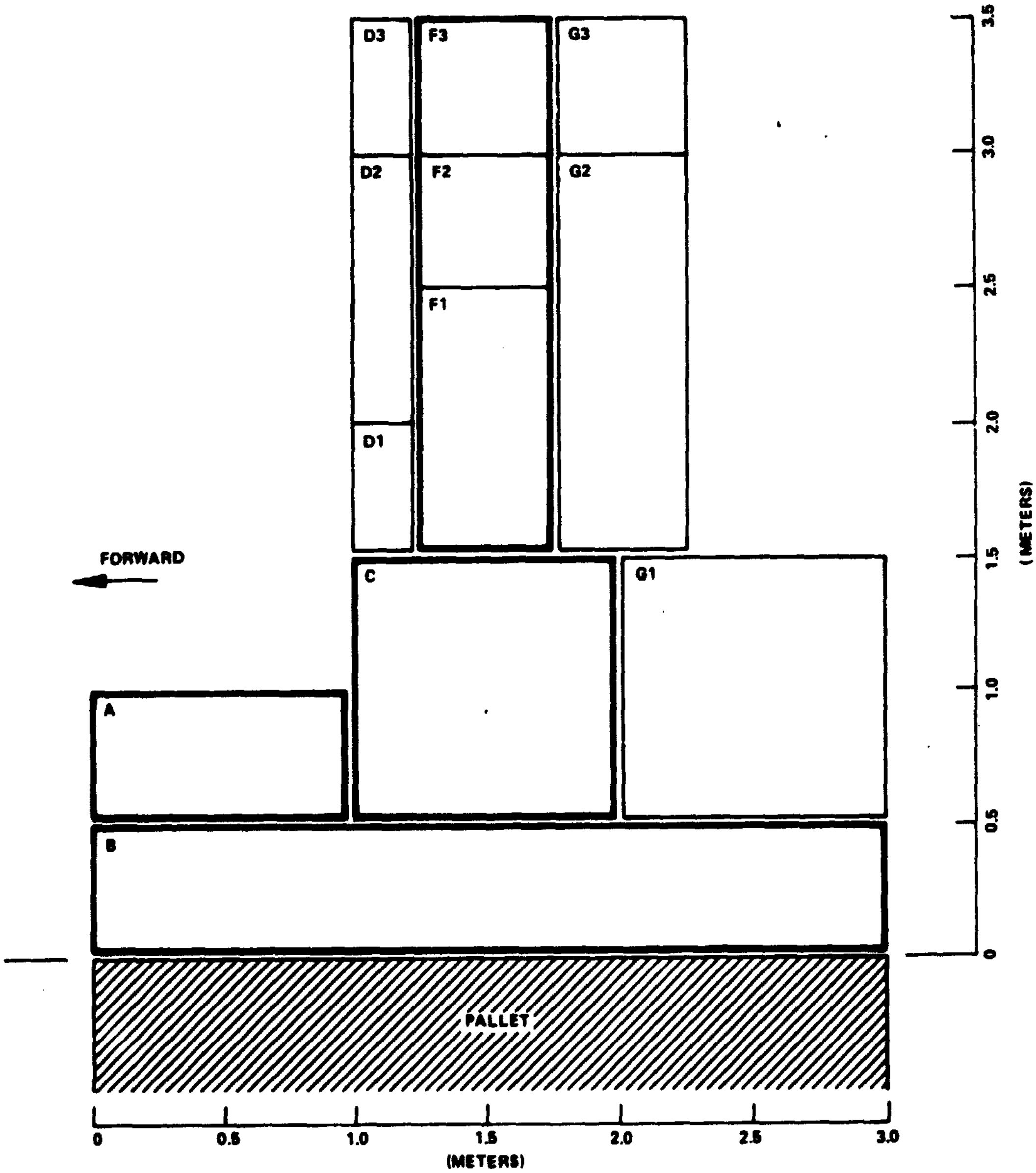


Figure 5-3.- AMPS Particle Accelerator System Y-axis view looking starboard.

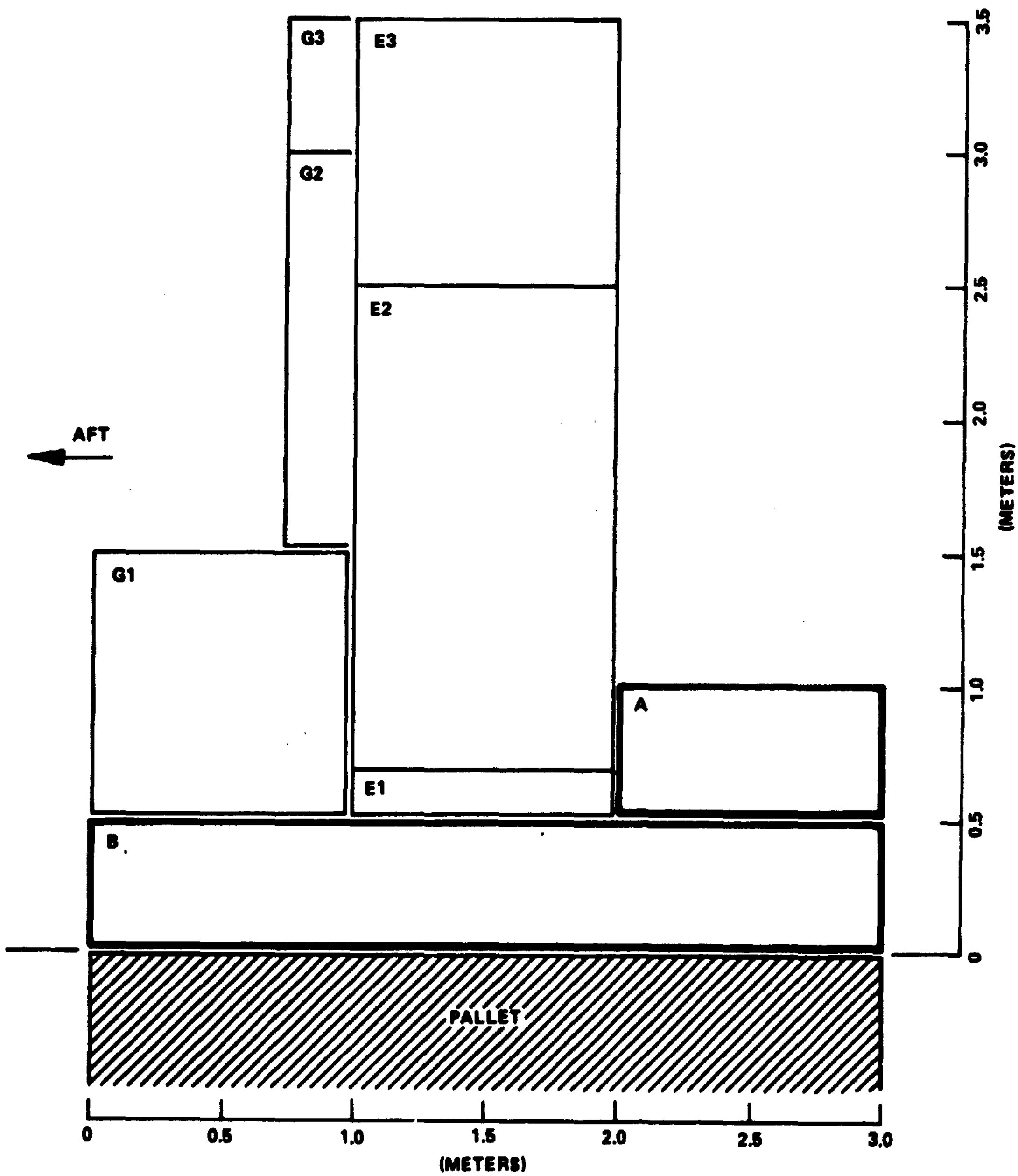


Figure 5-4.- AMPS Particle Accelerator System Y-axis view looking port.

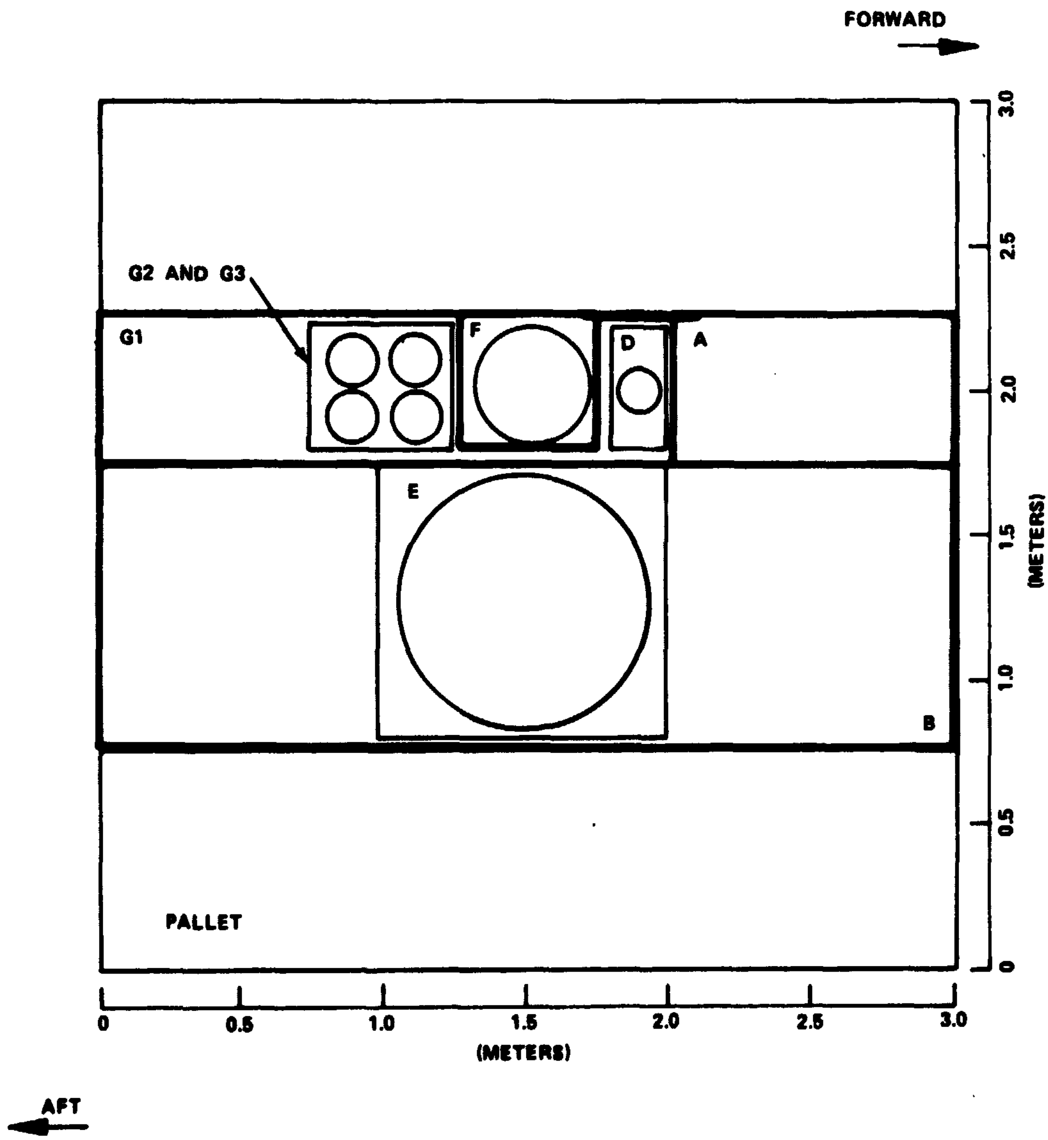


Figure 5-5.- AMPS Particle Accelerator System Z-axis view looking down.

Susystems	Dimensions, meters	Volume, cu m	Weight, kg
Power unit (A)[1]	0.5 x 1.0 x 0.5	0.25	45
Capacitors (B)[1]	0.5 x 3.0 x 1.5	2.25	540
Power unit (C)[1]	1.0 x 1.0 x 0.5	0.5	110
Ion accelerator (F1, F2, F3)	2.0 x 0.5 x 0.5	0.5	105.5
Pulse program box (F4)[2]	-	0.02	4.5

Note: [1]If the Electron Accelerator (Instrument 303), Magnetoplasmadynamic (MPD) Arc (Instrument 304), and the High Voltage Plasma Gun (Instrument 306) are also flown, they will share some of the same subsystems.

[2]The pulse program box will be located on the operator's console.

5.4.3 Operation

5.4.3.1 Pointing requirements.- The accuracy of pointing the axis of the ion accelerator should be within ±2°.

5.4.3.2 Stabilization.- The allowable rate of angular change while pointing should be 1 deg/sec or less.

5.4.3.3 Orbiter attitude.- The attitude of the Orbiter should be known to within ±2°.

5.4.3.4 Timeline of operation.- The Ion Accelerator will operate for a maximum of 4 hr/day with a maximum energy expenditure of 40 kWh/day. The standby mode of operation will occur only during this operational period.

5.4.3.5 Constraints.- Operation of the accelerator should take place in the ionosphere at a minimum altitude of 200 km. Pointing of the ion beam with respect to the direction of the ambient magnetic field may not be arbitrary because of the possibility of beam return and collision with the Orbiter caused by the gyromotion of the beam particles in the field. Thermal and vehicle charging problems might be created depending upon the return beam energy and intensity. Details of possible pointing constraints have not been determined. However, the firing of the ion accelerator should be restricted by a GO/NO GO command generated

by a magnetometer, namely, the Vector Magnetometer (Instrument 548) which will also be on the Orbiter.

5.4.4 Checkout and Test

5.4.4.1 Boresighting requirements.- The only requirement will be that which is necessary to achieve the ±2° pointing accuracy.

5.4.4.2 Prelaunch checkout.- Low voltage subsystems will be activated and housekeeping parameters recorded. The pulse sequence should be initiated; however, the high voltage cannot be tested because high-voltage operation will be precluded at atmospheric pressure.

5.4.4.3 Preflight calibration.- No preflight calibrations are required.

5.4.4.4 Inflight calibration.- Inflight calibration will be performed with the AMPS Particle Accelerator Diagnostic Instruments 549 and 550, if flown. Details of the calibration and frequency have not been determined. The calibrations will probably encompass a measurement of beam energy, intensity, and a two-dimensional spatial profile.

5.4.5 Controls

The Ion Accelerator will be controlled from a console in the Orbiter aft crew station. The accelerator design will require approximately 14 control functions transmitted to the pallet-mounted subsystems for operational control. Included in these will be the following:

Subsystem	Controlled Parameters
A	Capacitor bank charge current
C	High voltage switch (HVS I) (four positions)
C	Power processing unit I (PPU I) output voltage
C	Power processing unit I (PPU I) output current
F	Bombardment voltage
F	Bombardment current
F	Beam neutralizer heater voltage

Subsystem	Controlled Parameters
F	Beam neutralizer keeper voltage
F	Plenum pressure
F	Beam neutralizer pressure
F	Accelerated current
F	Acceleration voltage
F	Acceleration grid potential
-	Control console power on/off

Details of implementing these controls have not been determined. However, the design will probably require analog control lines, that are capable of supporting the signal bandwidths up to 1 MHz, from the console to the accelerator subsystems. Several of the control functions will need rapid time sequencing. This will be accomplished by a programmable pulse program box. Design details of the box have not been determined.

5.4.6 Displays

Approximately 20 to 25 parameters relating to accelerator operation will require display. Some will be slowly varying, while others can occur with bandwidths up to 0.1 MHz and will be transient (one-shot) pulses. It will be necessary to view the pulse shapes of a number of the rapidly varying parameters correlated in time. In addition, some of these pulse shapes will need to be permanently stored as scientific data. Probably the best way to accomplish display of the pulsed parameters will be with several fast digitizers with selectable sampling rates up to 1 MHz and storage of the digitized pulse shapes in memories for immediate recall to a cathode-ray tube (CRT) display. The parameters which will require pulse shape display are:

Sustem	Parameter
C	Output voltage (power processing unit II)
C	Output current (power processing unit II)
F	Bombardment voltage
F	Bombardment current

System	Parameter
F	Beam neutralizer heat voltage
F	Beam neutralizer keeper voltage
F	Plenum pressure
F	Beam neutralizer pressure
F	Accelerated current
F	Acceleration voltage
F	Acceleration grid potential

In addition to these parameters, all operational and housekeeping parameters should be sampled at a lower rate and displayed, probably on a CRT with commandable digital format. It is estimated that there will be 20 to 25 such parameters.

5.4.7 Data

5.4.7.1 Scientific.- The Ion Accelerator will generate slowly varying and pulsed (as fast as 0.1 MHz bandwidth) parameters. Scientific data storage will require retaining the pulse shapes of several of the pulse parameters. For the rapidly varying parameters, probably the best way to handle the data will be with fast digitizers with selectable sampling rates to 1 MHz and storage of the digitized parameters' associated memories (already mentioned in Display paragraph) before merging into the Orbiter systems. There will be two such accelerator scientific parameters. These are as follows:

System	Parameter	Bandwidth (MHz)	Bit Rate (kbps)
F	Accelerated current	0.1	1.5
F	Accelerated voltage	0.1	1.5

5.4.7.2 Housekeeping.- Time varying and dc parameters will be stored and merged with the scientific data. The peak or average values of the time varying parameters will be stored. It is estimated that there will be 20 to 25 housekeeping parameters which should be sampled at 0.1 sample per second, digitized to 8-bits for a total rate of approximately 20 bits per second

5.4.8 Development Status

5.4.8.1 Forerunner instruments.- Ion accelerators with fractional ampere output have been flown in space. At the present time, laboratory multi-aperture ion accelerators with ampere outputs are coming into existence.

5.4.8.2 Problems.- The problems associated with this experiment are discussed in the following subparagraphs.

5.4.8.2.1 Design and manufacturing: Production of this system will require significant design and development effort, particularly in the ion source and capacitor bank subsystems.

5.4.8.2.2 Operational: Corona and high-voltage discharge problems will be possible. In addition, beam instabilities caused by the ambient space plasma in the vicinity of the Orbiter may occur. The problem of vehicle neutralization will require significant study to ensure that the method proposed for this instrument is adequate.

5.5 HIGH VOLTAGE PLASMA GUN - INSTRUMENT 306

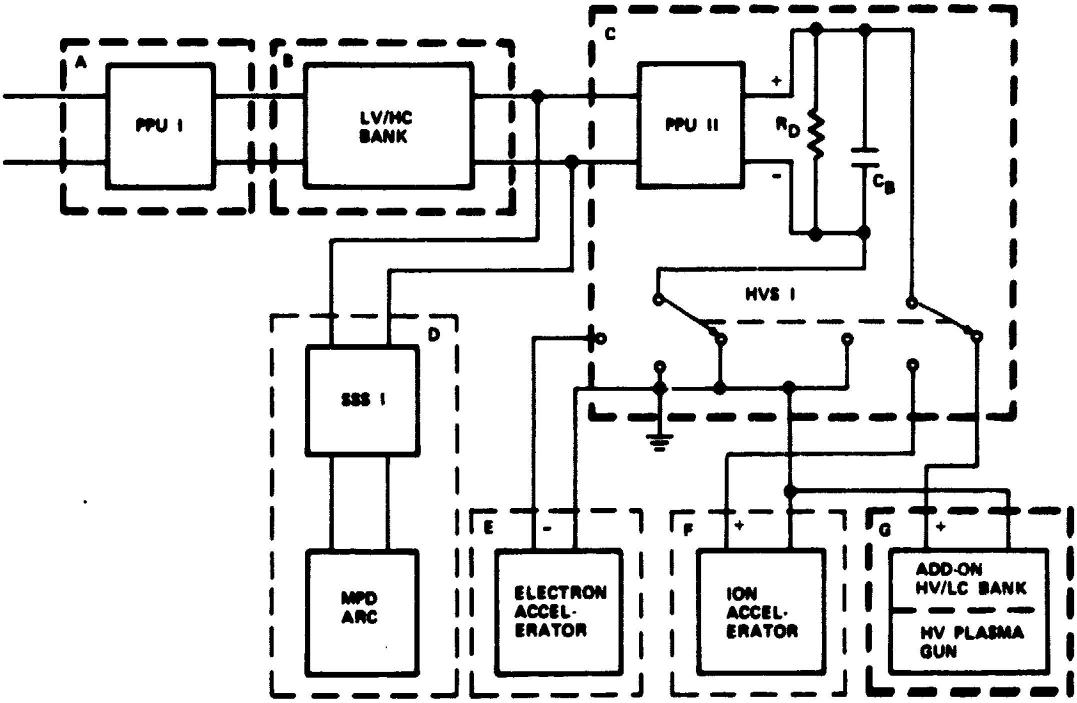
5.5.1 Objective

The High Voltage Plasma Gun will be utilized to perform experiments involving the excitation of neutral and plasma components in the upper atmosphere and ionosphere, the tracing and mapping of magnetic field lines of the earth, and the generation of plasma waves and disturbances in the ionosphere.

5.5.2 General Description

5.5.2.1 Location.- This instrument will be mounted on the pallet.

5.5.2.2 Configuration.- The High Voltage Plasma Gun (HVPG) will be a subsystem of the AMPS Particle Accelerator System (see figure 5-6). In this system, Orbiter-furnished 28 Vdc power will be converted to 500 Vdc by subsystem A, and the charge will be stored in a capacitor bank (subsystem B) for high-intensity pulsed operation. Subsystem B will feed a voltage converter capable of outputs to 10 kV, and this supply will feed a high-voltage capacitor bank (part of subsystem G) for high-intensity, high-voltage pulses. In operation, a gas of the plasma species desired will be pulsed into a chamber in the HVPG, and at a predetermined pressure, the high voltage will be applied to a cathode of a two-electrode structure. A high-intensity discharge will be initiated, and the plasma



SUBSYSTEM	ELEMENTS
A	POWER PROCESSING UNIT (PPU) I (28V/400A/ /500V/23A)
B	LOW VOLTAGE/HIGH CAPACITANCE (LV/HC) BANK (500V/0.8F)
C	PPU II (500V/400A/ /30,000V/10A), DRAINAGE RESISTOR (R_D), BUFFER CAPACITOR (C_B), HIGH VOLTAGE SWITCH (HVS) I
D	SOLID STATE SWITCH (SSS)1, MAGNETOPLASMADYNAMIC (MPD) ARC (500V/200,000A)
E	ELECTRON ACCELERATOR (30,000V/7A)
F	ION ACCELERATOR (20,000V/10A)
G	ADD-ON HIGH VOLTAGE/LOW CAPACITANCE (HV/LC) BANK, HIGH VOLTAGE (HV) PLASMA GUN

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Figure 5-6.- AMPS Particle Accelerator System.

(ions and electrons) will be ejected through the exit aperture of the gun by virtue of the interaction between the plasma and the magnetic field set up by the discharge current.

The High Voltage Plasma Gun will operate with a variety of instruments including its own diagnostic package (to be determined) and also ion mass analyzers, electron detectors, spectroradiometric instruments, television, and wave receivers.

5.5.2.3 Specifications.-

5.5.2.3.1 Voltage: The input voltage shall be 1000 to 10,000 V.

5.5.2.3.2 Energy spread ($\Delta E/E$): The energy spread shall be a maximum of 0.5.

5.5.2.3.3 Current output: The current output shall be 10,000 to 250,000 A per gun, parallel operation of four guns is possible.

5.5.2.3.4 Energy storage: Energy storage will be accomplished through a 20 kJ, 400 μF, 10,000 V capacitor bank.

5.5.2.3.5 Operating mode (pulsed): The pulse length will be determined by the energy storage bank capacitance and voltage and by the voltage and current of the gun.

5.5.2.3.6 Gas species: The gas species will cover a complete range of laboratory gases.

5.5.2.3.7 Beam (plasma) angular divergence: The beam angular divergence will be $\pm 30^\circ$ maximum.

5.5.2.3.8 Pitch angle variation: The pitch angle variation will be 180°, and will be accomplished by means of vehicle orientation

5.5.2.3.9 Power input: The power input voltage will be 28 Vdc with a standby power usage of 400 W. The average power usage will be 5 kW and the maximum power usage will be 10 kW. The maximum energy consumption will be 40 kWh/day.

5.5.2.3.10 Physical dimensions: The physical dimensions of the High Voltage Plasma Gun and its driving systems are shown in figures 5-7, 5-8, and 5-9. Other physical characteristics of the instrument parts are shown in the following table.

Subsystems	Dimensions, meters	Volume, cu m	Weight, kg
Power unit (A)[1]	0.5 x 1.0 x 0.5	0.25	45
Capacitor bank (B)[1]	0.5 x 3.0 x 1.5	2.25	540
Power unit (C)[1]	1.0 x 1.0 x 0.5	0.5	110
Plasma gun (G1, G2, G3)	1.0 x 1.0 x 0.5	0.7	105
Pulse program box (G4)[2]	-	0.02	5

Notes: [1]If the Ion Accelerator (Instrument 301), Electron Accelerator (Instrument 303), and the Magnetoplasmadynamic (MPD) Arc (Instrument 304) are also flown, they will share some of the same subsystems.

[2]The pulse program box will be located on the operator's console.

5.5.3 Operation

5.5.3.1 Pointing requirements.- The axis of the gun output ports should be pointed within ±2°.

5.5.3.2 Stabilization.- The allowable rate of change of pointing should be a maximum of 1 deg/sec.

5.5.3.3 Orbiter attitude knowledge.- The attitude of the Orbiter should be known to within ±2°.

5.5.3.4 Timeline of data takes.- Planned instrument operation will be a maximum of 4 hr/day for a maximum Orbiter electrical energy expenditure of 40 kWh/day.

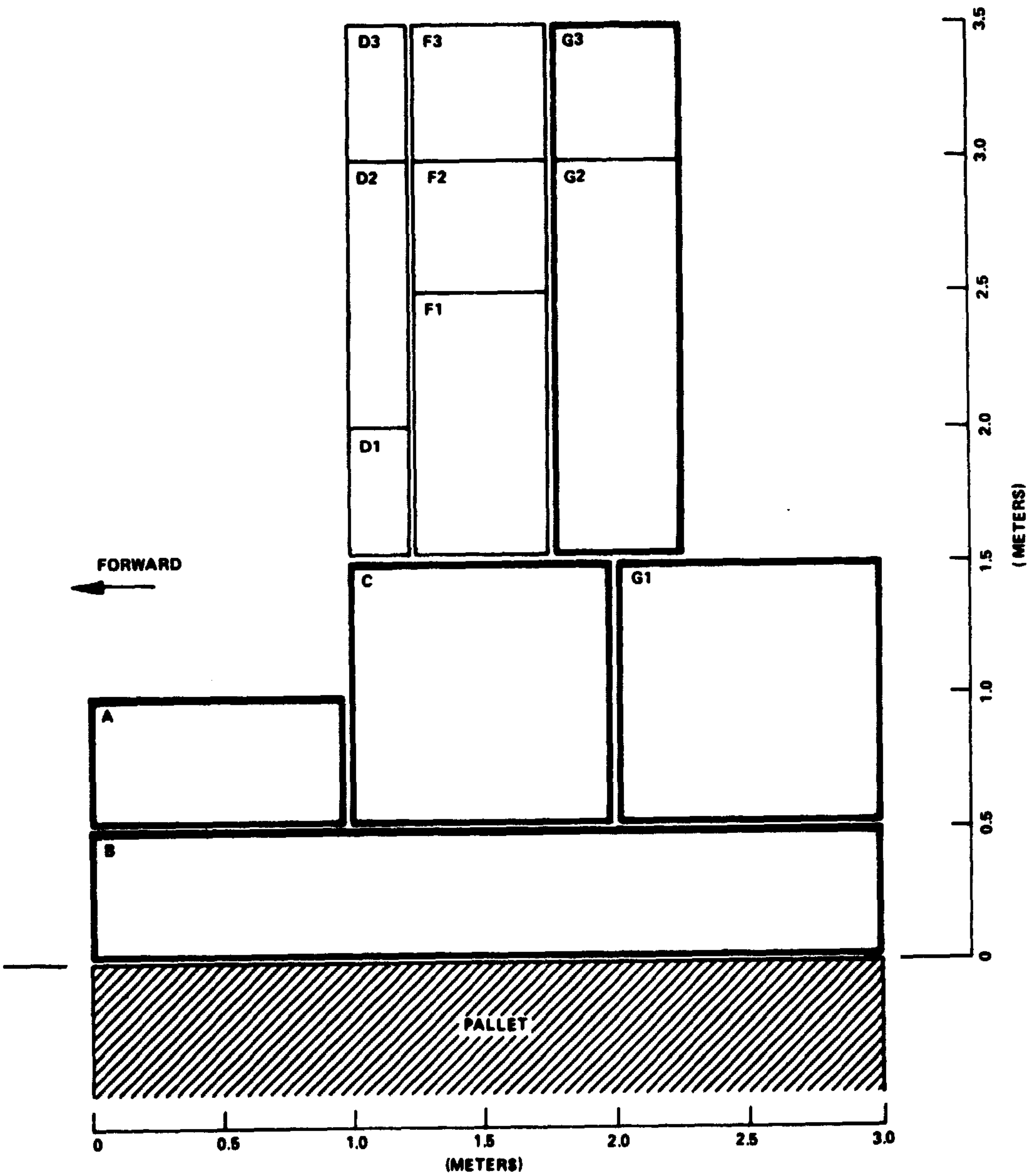

Figure 5-7.- AMPS Particle Accelerator System Y-axis view looking starboard.

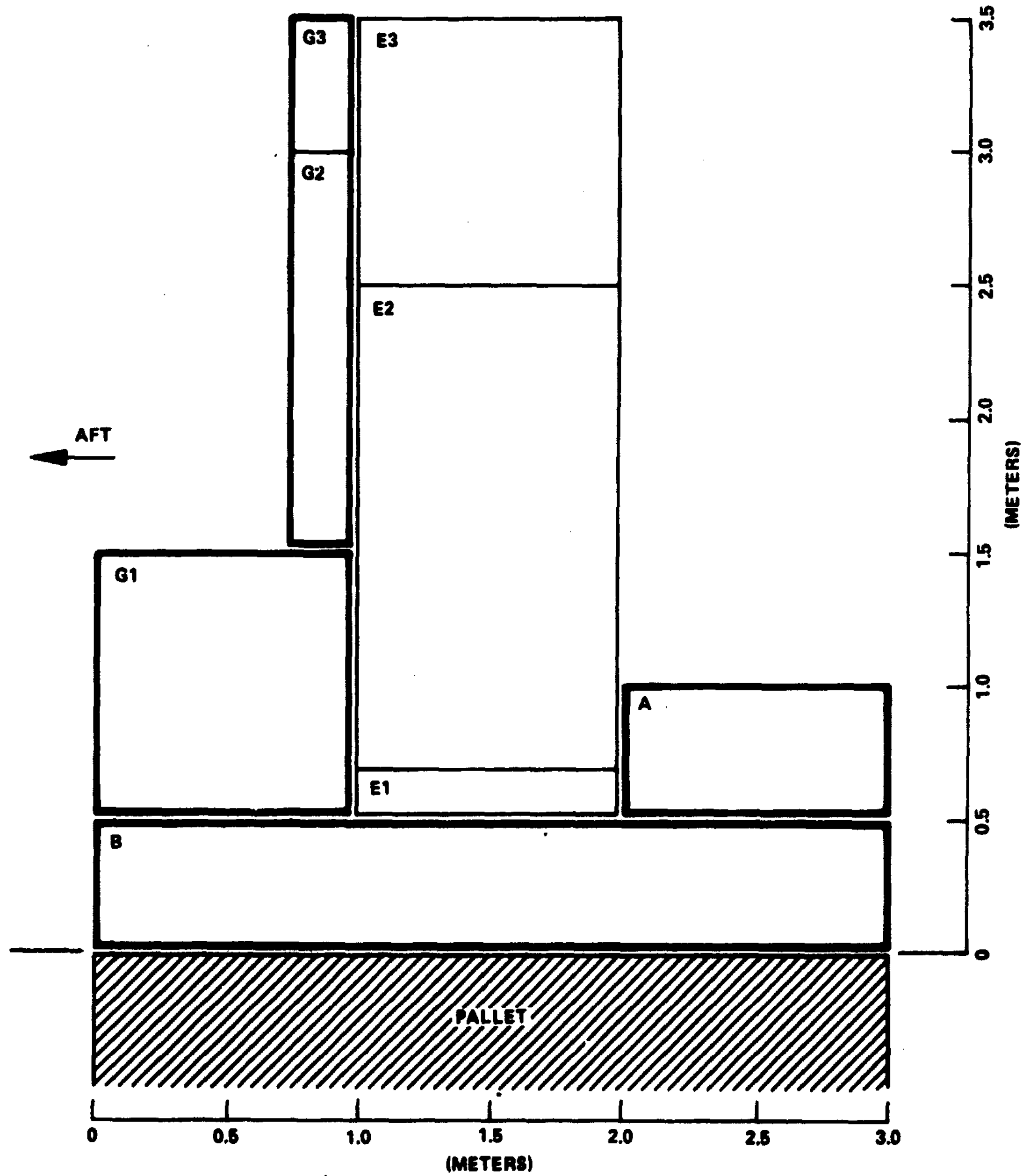

Figure 5-8.- AMPS Particle Accelerator System Y-axis view looking port.

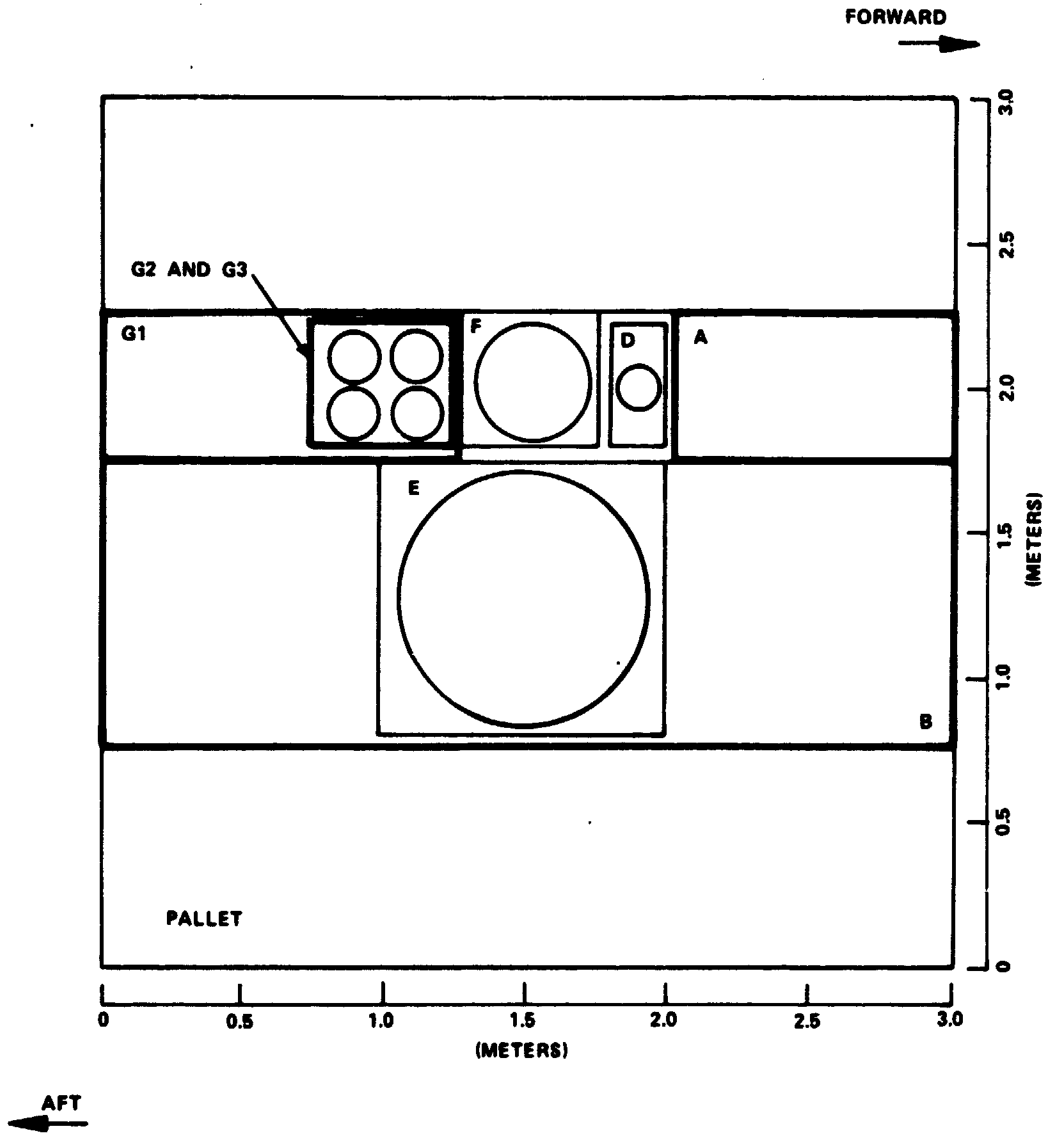

Figure 5-9.- AMPS Particle Accelerator System Z-axis view looking down.

5.5.3.5 Constraints.- The High Voltage Plasma Gun should operate at altitudes exceeding 200 km. Pointing of the plasma beam with respect to the direction of the ambient magnetic field may not be arbitrary because of the possibility of beam return and collision with the Orbiter caused by the gyromotion of the beam particles in the field. Thermal, X-radiation, and vehicle charging problems might be created depending upon return beam energy and intensity. Details of possible pointing constraints are to be determined. However, the firing of the high voltage plasma gun should be restricted by a GO/NO GO command generated by a magnetometer, namely, the Vector Magnetometer (Instrument 548), which will also be on the Orbiter.

5.5.4 Checkout and Test

5.5.4.1 Boresighting requirements.- They will be only as required to meet the $\pm 2^{\circ}$ pointing accuracy.

5.5.4.2 Prelaunch checkout.- The low-voltage subsystems will be activated and housekeeping parameters checked. A plasma pulse sequence will be initiated, but the gun will not be fired as this operation will be precluded at atmospheric pressure (i.e., hig-voltage systems could not be exercised). Pulse parameters during the sequence will be monitored. A GSE gas system will be required to service the gas storage system for the High Voltage Plasma Gun.

5.5.4.3 Prelaunch calibration.- No prelaunch calibration is required.

5.5.4.4 Inflight calibration.- Inflight calibration should be carried out by means of a package of boom-mounted plasma diagnostic instruments. Details of the package and frequency of calibration are to be determined.

5.5.5 Controls

The High Voltage Plasma Gun will be controlled from a console in the Orbiter's aft crew station. The gun design will require the following controls:

System	Controlled Parameters
A	Capacitor bank charge current
C	Power processing unit II (PPU II) output voltage
G	Capacitor bank voltage

System	Controlled Parameters
G	Plenum pressure
G	High voltage switch I (HVS I) (three positions)
-	Control power on/off

5.5.6 Display

Proper control of the accelerator will require the display of the pulse waveforms of four analog transient pulses. The waveforms will have bandwidths to 1 MHz and should be digitized with fast analog-to-digital converters with selectable sampling frequencies to 10 MHz and with associated memories for recall to a (CRT) cathode ray tube display. These parameters will be:

Subsystem	Parameters
C	Power processing unit II (PPU II) output voltage
C	Power processing unit II (PPU II) output current
G	Discharge current
G	Discharge voltage

In addition, there will be 12 to 18 housekeeping parameters including the above in-house digital values which will be displayed on a CRT.

5.5.7 Data

5.5.7.1 Scientific.- The scientific data will consist of the pulse waveforms of two parameters rapidly digitized to 8-bit words. The parameters are in the following table.

Subsystem	Parameters	Bandwidth (MHz)	Bit rate (kbps)
G	Discharge current	1	0.5
G	Discharge voltage	1	0.5

5.5.7.2 Housekeeping.- there will be 12 to 18 housekeeping parameters whose peak or average values must be sampled at 0.1 sample per second, digitized to 8-bit words for a total rate of approximately 15 bits per second.

5.5.8 Development Status

5.5.8.1 Forerunner instruments.- Plasma accelerators with the capabilities of the present accelerator exist as ground-based laboratory instruments. A plasma accelerator similar to the present accelerator, but with significantly lower output intensity has flown on at least one unmanned rocket.

5.5.8.2 Problems.- Problems associated with the development of this instrument are discussed in the following paragraph.

5.5.8.2.1 Design and manufacturing: The design of the plasma gun and the low- and high-voltage capacitor banks will require considerable design effort.

5.5.8.2.2 Operational: Problems associated with corona and high voltage may exist. In addition, instabilities in the plasma beam caused by the ambient plasma in the vicinity of the Orbiter may occur.

5.6 RADIO FREQUENCY SOUNDER - INSTRUMENT 405

5.6.1 Objective

The Radio Frequency Sounder will provide real-time information on the state of the ionosphere at and remote from the Orbiter (up to hundreds of kilometers) and will provide a general research tool for studies in a wide variety of plasma-wave phenomena stimulated by the transmitted wave.

5.6.2 General Description

5.6.2.1 Location.- This instrument will be mounted as follows:

a. Transmitter/receiver - on the pallet

b. Antenna (gimbal mounted) - on the boom

c. Receiver - on the subsatellite

d. Antenna - on the subsatellite

5.6.2.2 Configuration.- Traditional sounder operation will be to transmit and receive a radio frequency (RF) pulse using a single antenna and to monitor the received signal for a time period which is long compared to the pulse duration. Using fixed or swept frequency transmitting and receiving modes, the return signal can be processed in regards to time, frequency, amplitude, and phase to yield the ionospheric information. The proposed sounder will have swept or fixed frequency, variable peak pulse power, variable pulse width and shape, and variable pulse repetition frequency. The transmitter/receiver (T/R) antenna length will be variable (furlable) from 3 meters for plasma physics experiments out to 100 meters tip-to-tip for sounder operation. See figure 5-10 for the overall concept.

The transmitter and one receiver will be pallet mounted, but the antenna will be gimbal mounted (having its own positioning system) on the 20- to 50-m boom to reduce EMI and magnetic field problems. The antenna will be gimbaled for alignment with the earth's magnetic field or Orbiter's velocity vector. A second receiver will be subsatellite mounted for spacing away from the transmitter. It will also have a long, furlable antenna.

5.6.2.3 Specifications.- The specifications for this instrument are listed in the following subparagraphs.

5.6.2.3.1 Frequency: This instrument will operate in swept frequency and fixed frequency modes between 100 kHz and 20 MHz. The receivers will be coupled to the transmitter, and operation will be programmable.

5.6.2.3.2 Bandwidth: The receiver bandwidth will be narrow, and will vary with frequency.

5.6.2.3.3 Sensitivity: The receivers will have a sensitivity of 1 μV.

5.6.2.3.4 Data collection rate: The data collection rate will be 512 samples per second digital. There will also be analog data at 30 kHz and 2 MHz rates.

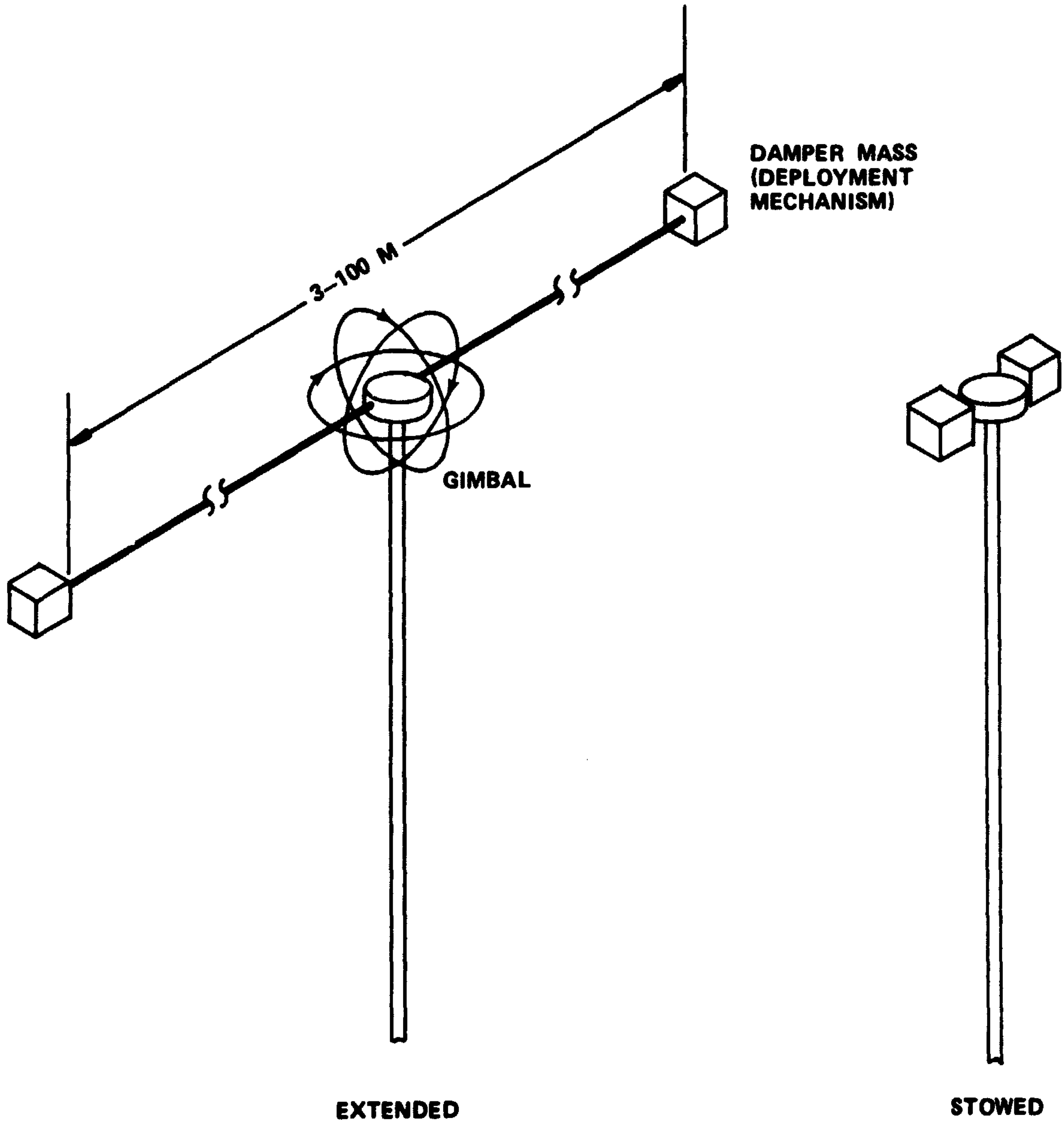

Figure 5-10.- Antenna configuration.

5.6.2.3.5 Power: The power requirements are as follows:

a. Transmitter average power - 50 W

b. Receiver 1 average power - 10 W

c. Receiver 2 average power - 10 W

The total power required from the Orbiter will be about 100 W. Receiver 2 will be mounted on a subsatellite. The power to deploy the antennas is estimated at 30 W. The power required for a gimbal platform for the antenna will be 75 W at 28 Vdc. Transmitted power will be variable from 0 to 1 kW.

5.6.2.3.6 Physical dimensions: The physical characteristics of size and weight are as follows:

a. Transmitter - 0.3 cu m and 30 kg

b. Receiver 1 (pallet installation) - 0.1 cu m and 5 kg

c. Receiver 2 (subsatellite installation) - 0.1 cu m and 5 kg

d. Boom-mounted antenna - 0.1 cu m and 50 kg

e. Subsatellite antenna - 0.05 cu m and 25 kg

This instrument will be pallet mounted with a separate subsatellite-mounted receiver. The Orbiter antenna will be boom mounted and will require at least one and possibly two types of magnetometers to cancel out the effect of the earth's magnetic field from the data. It will also require a gimbal mount to align the dipoles with the earth's magnetic field or the Orbiter's velocity vector.

5.6.3 Operation

5.6.3.1 Pointing requirements.- The transmitting (boom-mounted) antenna must be adjustable and independent of Orbiter orientation. Its attitude must be known within plus or minus 1° with respect to the Orbiter's velocity victor or the magnetic field direction.

5.6.3.2 Stabilization.- The stabilization requirements are yet to be determined.

5.6.3.3 Timeline.- The timelines will vary with the type of experiment being accomplished; timelines will be prepared for each experiment.

5.6.3.4 Constraints.- Magnetic field contamination must be less than 300 gamma at the fluxgate magnetometer and less than 20 gamma at the Rb vapor magnetometer. The antennas must be of a nonmagnetic material such as BeCu alloy.

EMI should be below the receiver sensitivity of 1 μV, thereby necessitating a remote, boom-mounted antenna. Positioning of this antenna independent of the Orbiter attitude will require a gimbal mount. The strength and direction of the magnetic field vector must be known. Direction must be known to within plus or minus 1° and field strength to 0.1 percent. Direction can be measured with a triaxial fluxgate, but this type of sensor may not be able to measure field strength to the accuracy required, thus necessitating the use of a Rb vapor magnetometer. Magnetometers should be mounted on the boom close to the antenna.

5.6.4 Checkout and Test

Antennas patterns will be important and very difficult to measure.

5.6.5 Controls

The following controls will be required to optimize the received signals.

5.6.5.1 Transmitter.- The following transmitter controls will be required.

a. Power on/off

b. Power level - 0 to 1 kW

c. Frequency mode - swept or fixed

d. Pulse width - 10 μs to 100 ms

e. Pulse repetition frequency - 10 to 1000 pps

f. Pulse shape - square, Gaussian, sine, etc.

g. Frequencies transmitted - capable of more than one at a time

5.6.5.2 <u>Receiver</u>.- The following receiver controls are required:

a. Power on/off

b. Frequency mode

c. Bandwidth selection

5.6.5.3 <u>Antenna</u>.- The following antenna controls are required:

a. X, Y, Z orientation

b. Dipole length

The receiver and antenna controls will be duplicated for the subsatellite-mounted unit. All controls may be preprogrammed and operated by a computer.

5.6.6 Displays

A real-time ionogram display will be required during sounder operation. For transmission experiments, plots of receiver amplitude versus time will be needed. Display of subsatellite location and attitudes may be needed, but has not been specified. Magnetic vector data may also be useful.

5.6.7 Data

5.6.7.1 <u>Scientific</u>.- The follcwing scientific data types are provided.

5.6.7.1.1 Transmitter: Frequency information: digital, 0 to 5 V, 8 bits, 2 channels, 512 sps

5.6.7.1.2 Receivers (both units):

Video: analog, 30 kHz

Intermediate frequency (IF): analog, 2 MHz

Transmitter AGC: digital, 0 to 5 V, 8 bits, 2 channels, 512 sps

Frequency information: digital, 0 to 5 V, 8 bits, 2 channels, 512 sps

5.6.7.2 Housekeeping.- The housekeeping data will have the following characteristics:

Status Data: digital, 0 to 5 V, 8 bits, 4 channels, 60 sps

Although not specified, antenna status may be required, along with subsatellite attitudes and location and magnetic vector data.

5.6.8 Development Status

5.6.8.1 Forerunner instruments.- There have been many successful ionospheric sounders flown on rockets and satellites. A list of references may be found in this instrument's functional requirements document.

5.6.8.2 Problems.- No major problems should be encountered in the design and manufacture of the transmitter and receivers. The boom-mounted antenna and its deployment may cause difficulties. Operational problems will almost all be related to RF and magnetic EMI.

5.7 ULF ANTENNA AND ULF TRANSMITTER - INSTRUMENT 407

5.7.1 Objective

There are two instrument objectives. The first objective is to investigate radiation properties at ultra-low frequencies (ULF) of a long thin-wire dipole in magnetospheric plasma when excited by a pallet-mounted ULF transmitter and current flowing in the wire because of natural electrostatic fields and v x B effect. The second objective is to investigate the propagation inside and outside the magnetosphere of ULF waves, including artificial micropulsations, generated by ULF radiation.

5.7.2 General Description

5.7.2.1 Location.- The instrument will be mounted on the pallet.

5.7.2.2 Configuration.- This instrument will consist of a ULF transmitter, an antenna test set (receiver), and an antenna subassembly suitable for deployment and monitoring a 100-km wire dipole that extends 50 km on each side of the Orbiter. The first two items are to be mounted in a pressurized area while the antenna subassembly will be on an inertial platform mounted to a pallet.

The transmitter will be tunable over the ULF range of dc to 5 Hz and will have an adjustable power output. The antenna test set will be similar in operation to a unit which is now used to monitor high tension power lines. The antenna test set will be used to monitor the electromagnetic behavior of the dipole, measure current distribution, measure impedance at the midpoint, and measure discontinuities due to nonlinear magnetoplasma effects and other possible perturbations.

The antenna subsystem will consist of the 100-km dipole complete with a reeling/unreeling mechanism. This will have a variable speed motor and brake, reduction gearing, variable and controllable drag area devices, and sensors of the terminating mass/electrode position at the wire's free end and of the wire tension. Included will be a control system complete with remotely operated devices and computing logic. The control system will be required to achieve wire configurations that are safe to the navigation and physical integrity of the Orbiter.

The emitted electromagnetic field will be measured by use of the Tethered Satellite for ULF Magnetospheric Measurements (Instrument 408) or a maneuverable subsatellite. This is to be done only if a subsatellite is available as a general purpose AMPS facility.

5.7.2.3 Specifications.- The following specifications apply to this experiment instrument.

5.7.2.3.1 Frequency: The transmitter will be tunable from 0.1 to 5 Hz.

5.7.2.3.2 Resolution: The resolution of the instrument is to be determined.

5.7.2.3.3 Sensitivity: The sensitivity of the instrument is to be determined.

5.7.2.3.4 Data collection rate: Up to 100 samples per second depending on the bandwidth of the parameter.

5.7.2.3.5 Power: The transmitter will have an adjustable carrier wave (cw) output to the antenna of 0 to 2 kW. Power input required will be as follows for the various subsystems.

a. Transmitter - 110 V, 400 Hz: 50 W (standby), 1 kW average to 2.5 kW maximum (operating)

b. Antenna test set - 100 V, 400 Hz: 5 W (standby), 25 W average and 25 W maximum (operating)

The antenna subsystem will include a 100-km wire dipole (50-km each side) which will require:

a. Reeling/unreeling mechanisms equipped with variable speed motor/brake, reduction gears, variable and controllable drag area devices - 28 Vdc: 50 W (standby), 500 W average to 1.5 kW maximum (operating).

b. Sensors to locate the terminating mass/electrode position at the wire's free end and sensors to measure wire tension combined with a control system complete with remotely operated devices - 110 Vac, 500 Hz: 10 W (standby), 50 W average to 250 W maximum (operating)

5.7.2.3.6 Physical dimensions: The physical characteristics of this instrument is as follows:

a. Transmitter - 0.5 cu m and 75 kg

b. Antenna test set - 0.01 cu m and 10 kg

c. Antenna subsystem - 1.0 cu m and 150 kg

5.7.2.3.7 Other: Part of this experiment's objective will be to monitor and map the electromagnetic field of the antenna. A tethered satellite has been recommended for this purpose, but a subsatellite that can be positioned will also be appropriate. The satellite will require three-axis sensors to measure the electric field and the magnetic field.

5.7.3 Operation

5.7.3.1 Pointing requirements.- There will be no special pointing requirements.

5.7.3.2 Stabilization.- The method used to connect the antenna to the Orbiter will impose limitations on the maximum Orbiter angular excursions and rates. The outputs of the inertial platform will be required to perform active control of the wire deployment and retrieval and to choose the wire's equilibrium configuration. Full orbital data will be required to exert control on the wire by forecasting and damping oscillations induced in the wire by orbital motion.

5.7.3.3 Timeline.- Deployment and retrieval of the dipole antenna will take approximately 1 day total. Once deployed, the antenna will be utilized about 30 percent of the time and will be in a standby status about 70 percent.

5.7.3.4 Constraints.- Orbiter excursions and rates will be obvious constraints. None are specified.

5.7.4 Checkout and Test

The checkout and test requirements are not yet determined.

5.7.5 Controls

The instrument will require the following minimum controls:

a. Power up controls

    1. Transmitter

    2. Antenna test set

    3. Antenna subassembly drive

b. Antenna deploy/retrieve initiation

c. Transmitter frequency

d. Transmitter power level

e. Monitor controls for the antenna test set such as:

    1. Current distribution in antenna

    2. Antenna input impedance

    3. Voltage standing wave ratio (VSWR)

    4. Antenna temperature

    5. Free wire and display call-up

Actual deployment and control of the antenna equilibrium configuration will be automatic and computer controlled as indicated in the preceding Power and Operation subparagraphs.

5.7.6 Displays

Visual displays will be required for:

a. Antenna current distribution

b. Antenna input impedance

c. Transmitter output power

d. VSWR

e. Antenna temperature

f. Position of free wire end

5.7.7 Data

Parameter to be measured	Analog or digital	Frequency range, Hz	Word length, bits	Number of channels	Samples per second
		Antenna			
Wire tension	A	dc to 10	7	3	1/10
Wire temperature	A	dc to 0.1	12	2	1/100
Wire current	A	dc to 5	10	4	1
Position (of wire's end)	A	dc to 100	10 (angular)	3	1
		dc to 100	17 (range)	3	1
		Antenna Test Set			
Input voltage	A	dc to 5	12	1	1
Impedance	A	dc to 5	9	2	2
Echo delay	D	1 kHz to 10 MHz	10	1	1
Echo shape	D	1 kHz to 10 MHz	12	1[a]	1

Note: [a]Samples taken in sequence (as transmitted).

Parameter to be measured	Analog or digital	Frequency range, Hz	Word length, bits	Number of channels	Samples per second
		Transmitter			
Frequency	D	dc to 5	10	1	1/10
Output power	A	dc to 5	12	1	1/10
VSWR	A	dc to 5	8	2	1/10
Primary power	A	dc to 400	12	1	1/100

5.7.8 Development Status

5.7.8.1 Forerunner instruments.- The forerunner instruments have yet to be determined.

5.7.8.2 Problems.- Design and manufacturing difficulties have yet to be identified; however in the operational area, the antenna system, its deployment and stabilization, will be the obvious problems. A study has been made, and the antenna system appears feasible. The transmitter, antenna test set, signal processing electronics, and control and display can be assembled from state-of-the-art components.

5.8 TETHERED SATELLITE FOR ULF MAGNETOSPHERIC MEASUREMENTS - INSTRUMENT 408

5.8.1 Objective

This instrument will measure the electromagnetic field intensity generated by the AMPS ULF Antenna and ULF Transmitter (Instrument 407) and will plot the antenna radiation diagram around the Orbiter/AMPS, at various distances.

5.8.2 General Description

5.8.2.1 Location.- This instrument will be located on a pallet.

5.8.2.2 Configuration.- This instrument will consist of three subassemblies which are a tether mechanism, a subsatellite, and a command/control telemetry link. These are discussed as separate items in the following subparagraphs.

5.8.2.2.1 Tether mechanism: The tether will be a 100-km wire of about 0.3- to 0.4-mm diameter of A-286 or type 302 stainless steel. This will be controlled by a reeling/unreeling mechanism equipped with a variable-speed motor/brake, reduction gearing, controllable variable drag area devices, sensors of the tethered satellite position, wire tension sensors, and a control system complete with remotely operated devices and computing logics. The subassembly will be mounted on an inertially stabilized platform. Volume aboard the Orbiter will not change with deployment.

5.8.2.2.2 Tethered subsatellite: The subsatellite will be connected at the free end of the tether and will have heat shielding and radiator fins (temperature control). It will be equipped with three-axis sensors of the electric vector and of the magnetic vector of the electromagnetic field. It also will perform its own system calibration. Its control functions and data telemetry will be performed over the tether or by the use of a microwave link.

5.8.2.2.3 Command control: The two-way command control will be accomplished by using the tether itself as a link or by direct line-of-sight microwave. Data from the subsatellite will be telemetered by the same link.

5.8.2.3 Specifications.- The following discussed specifications are applicable to this instrument.

5.8.2.3.1 Frequency: Not specified. The ULF Antenna and ULF Transmitter (Instrument 407) will operate at 0.1 to 5 Hz. The telemetry link will be at microwave frequencies to be determined.

5.8.2.3.2 Resolution: The instrument resolution is yet to be determined.

5.8.2.3.3 Sensitivity: The instrument sensitivity is yet to be determined.

5.8.2.3.4 Data collection rate: Up to 100 sps depending on bandwidth of the parameter being measured.

5.8.2.3.5 Power:

Subsystem	Voltage	Standby power, W	Average power, W	Maximum power, W
Tether	28 Vdc,	50 W	500 W	1500 W
mechanism	110 V, 400 Hz	10 W	50 W	250 W
Command control	110 V, 400 Hz	5 W	25 W	25 W

The subsatellite will carry its own primary power. Its consumption is estimated at 2 W in standby and 25 W when collecting data.

5.8.2.3.6 Physical dimensions: The physical characteristics in size and weight of this instrument are as follows.

a. Tether and tether mechanism - 0.1 cu m and 150 kg

b. Subsatellite - 0.1 cu m and 200 kg

c. Command control - 0.1 cu m and 10 kg

5.8.2.3.7 Other: The tether mechanism must be mounted on an inertial platform for proper subsatellite and tether control.

5.8.3 Operation

5.8.3.1 Pointing requirements.- There will be no special pointing requirements in the operation of this instrument, particularly when it is used in conjunction with the ULF Antenna and ULF Transmitter (Instrument 407).

5.8.3.2 Stabilization.- There will be limitations imposed on the maximum Orbiter angular excursions and rates by the method used to connect the tether to the Orbiter. The outputs of the inertial platform will be required to perform active control of the tether deployment and retrieval, to choose the tether configuration at equilibrium, and to control satellite position. Full orbital data will be required to control the tether by forecasting and damping oscillations induced in the tether by orbital motion.

5.8.3.3 <u>Timeline</u>.- Deployment and retrieval of the tethered satellite will require about 1 day total time. Once deployed, it will be operational about 90 percent of the time and in a standby status for about 10 percent. The satellite will be collecting data during deployment and retrieval.

5.8.3.4 <u>Constraints</u>.- Orbiter excursions and rates, once an orbital attitude has been established, will be difficult to maintain over long periods. Problems can be foreseen with this instrument and a 100-km dipole antenna deployed at the same time.

5.8.4 Checkout and Test

The checkout and test requirements have yet to be determined.

5.8.5 Controls

The instrument will require the following minimum controls:

a. Power up controls

   1. Tether mechanism

   2. Satellite

   3. Telemetry

b. Tether controls

   1. Deployment

   2. Retrieval

Deployment and retrieval, as well as actual satellite positioning, will require establishing a control loop starting with observables such as wire tension, temperature, and onboard computer simulation of satellite position. These input parameters will adjust control variables such as speed of deployment, variable drag areas, etc. The control variables will probably be computer controlled.

5.8.6 Displays

The following items will be displayed. Some additional will be needed if manual adjustment rather than computer control is used.

a. Status of controls

b. End of tether position

c. Tether temperature

d. Satellite skin temperature

e. Tether tension, AMPS, and satellite ends

5.8.7 Data

The data will be generated analog and converted to digital. The digital requirements are shown in table 5-I.

5.8.8 Development Status

5.8.8.1 Forerunner instruments.- No instruments of this configuration has been flown previously.

5.8.8.2 Problems.- The design and manufacturing problems have yet to be determined; however, operationally the deployment and stabilization will be the obvious problems with this instrument. A preliminary report, "Shuttle-Borne Skyhook: A New Tool for Low-Orbital-Altitude Research," Smithsonian Institution Astrophysical Observatory, September 1974, indicates that the required instrument is feasible. This instrument might be combined with the ULF Antenna and ULF Transmitter (Instrument 407), with the subsatellite being free flying, but positionable.

5.9 DOPPLER-TRACKING BISTATIC SOUNDER OF STS/AMPS WAKE - INSTRUMENT 409

5.9.1 Objective

This instrument will measure, using Doppler tracking techniques, the electron density distribution in the Orbiter wake and will measure the wake profile up to a distance of 10 km in the spherical volume around the Orbiter.

TABLE 5-I.- DATA REQUIREMENTS

Parameter	Frequency Range, Hz	Word Length, bits	Channels	Sampling Rate, sps
Subsystem 1 - Tether mechanism				
Wire tension	dc to 10	7	3	1/10
Wire temperature	dc to 0.1	12	2	1/100
Wire current	dc to 5	10	4	1
Satellite position	dc to 100	10 (angles) 17 (range)	3	1
Subsystem 2 - Satellite				
Temperature	dc to 0.1	12	2	1/10
Battery voltage	dc	7	2	1/100
Current calibrator[1]	dc to 5	11	6	1
Sensor's output[1]	dc to 5	10	6	1
Subsystem 3 - Command control				
AGC (AMPS receiver)	dc	8	1	1/100
Output power (satellite transmitter)	dc	8	1	1/100
AGC (satellite receiver)	dc	8	1	1/100
Output power (AMPS transmitter)	dc	8	1	1/100

Note [1]Sequential sampling.

5.9.2 General Description

5.9.2.1 Location.- This instrument will be mounted on the pallet and a subsatellite.

5.9.2.2 Configuration.- The instrument will use microwave Doppler tracking techniques to measure the Orbiter wake profile with the Orbiter in various attitudes to change its ram shape through the plasma. To do this, the sounder will be divided into three systems:

a. Pallet-mounted inverted transponder which will function as the master terminal of the sounding link;

b. Tethered satellite complete with a multifrequency phase-coherent transponder; and

c. Tether system capable of reeling/unreeling the subsatellite up to a distance of 10 km and of tracking the free end.

The instrument will accomplish its objectives by establishing a multi-frequency Doppler link between the Orbiter and the tethered subsatellite. The electron density and content between the Orbiter transponder and subsatellite transponder will cause Faraday rotation and phase changes in the signal. From the changes to the polarized microwave signal, the electron density distribution can be computed. Both transponders are to have linearly polarized antennas.

5.9.2.3 Specifications.- The following specifications apply to this instrument.

5.9.2.3.1 Frequency: It is expected that this instrument will be similar to the Apollo-Soyuz Test Project (ASTP) experiment MA089. For this reason, dual frequencies of 162 MHz and 324 MHz will be used.

5.9.2.3.2 Resolution/accuracy: The transponders will be able to measure frequency to an accuracy of 10^{-3} Hz. To do this, very stable oscillators (on the order of 1.5×10^{-12}/100 sec) will be required.

5.9.2.3.3 Field of view: The spherical volume around the spacecraft out to 10 km will be probed by this instrument. The actual field of view will be the column between the two transponders.

5.9.2.3.4 Data collection rate: Data sampling of 1 sps will satisfy the requirements of this instrument. Higher rates will have to be used if channels are combined.

5.9.2.3.5 Power: Orbiter power will be required for the reeling/unreeling mechanism and the pallet-mounted transponder. The transponder on the satellite will have its own primary power and will use about 1 W standby, 2.5 to 5 W average at operating levels, and 10 W maximum. The Orbiter installed hardware will use:

Hardware	Standby	Average	Maximum
Tether Mechanism	10 W	75 W	150 W
Reel support sensors	2 W	5 W	25 W
Transponder	2 W	5 W	20 W

The Orbiter-mounted transponder will have about 10 W input power to its antenna.

5.9.2.3.6 Physical dimensions: The physical characteristics of size and weight are as follows:

a. Tether mechanism (with supporting sensors and electronics) - 0.01 cu m and 15 kg

b. Satellite mounted transponder - 0.2 cu m and 20 kg

c. Orbiter transponder - 0.01 cu m and 10 kg

d. Linear polarization monopole - 25.4 cm long, 12.7 mm base diam tapering to 9.5 mm and 1 kg

5.9.3 Operation

Operation of this instrument will be initiated with the satellite and Orbiter transponders being turned on and checked out. The Orbiter will be put into the desired flight attitude. The tethered satellite will then be deployed in the Orbiter wake. The data take will start when the two transponders are about 1/2 km apart and continue to operate to a separation of 10 km. The satellite will be guided to a new position in the wake and reeled back. This will continue until the plasma is mapped to the scientist's requirements. By changing the attitude of the Orbiter in relation to the direction of travel, the ram shape and consequently the wake shape will differ and another mapping sequence will be made.

5.9.3.1 Pointing requirements.- Pointing accuracy in pitch, roll, and yaw will be 0.5°.

5.9.3.2 Stabilization.- Limitations to the spacecraft angular excursion and rate will be imposed by the mechanical solution adopted to connect the tether to the Orbiter.

Altitude in relation to orbital velocity will have to be controlled within 1° to 3° during wake shape measurements. Larger excursions than this will change the shape of the wake.

5.9.3.3 Timeline.- The speed of reeling/unreeling will dictate the time required for one round trip. The mechanism now proposed will take about 2 hours for each direction probed.

When deployed, the instrument will be utilized continuously. Overall time utilization for a one week sortie will be 30 percent operation, 70 percent in a standby status.

5.9.3.4 Constraints.- The Orbiter attitude will have to be held to a reasonable minimum for a 2-hour period during data take. This may be difficult because of Orbiter temperature control.

5.9.4 Checkout and Test

Complete antenna patterns will have to be made for this instrument. Also, measurements of frequency stability, phaselock, power outputs, noise, etc., will have to be made. Some of the above measurements, particularly frequency stability, should be repeated after the mission.

5.9.5 Controls

Tether operations will require a control loop that uses such inputs as wire tension and satellite position to control the tether configuration to optimize data and minimize risk to the spacecraft. This will require computer control operations. Manual controls will consist of:

a. Pallet transponder on/off

b. Satellite transponder on/off

c. Tether mechanism deploy/retrieve

d. Satellite positioning control (possibly joystick with computer feedback to CRT display)

5.9.6 Displays

The scientist has requested visual displays of the six automatic gain control (AGC) channels and six phase-lock indications. Unless he is aboard the Orbiter, these will be telemeterd to the ground for his use. Orbiter display will consist of control feedback information.

5.9.7 Data

The following table shows the data requirements for this instrument.

Parameter	Bandwidth, Hz	Word Length bits	Channels	Sampling rate, sps
Scientific, Orbiter				
Transponder				
AGC	dc to 10	8	3	1/100
Transmitter power out	dc to 1	8	3	1/100
Differential Doppler	digital	24	3	1
Rotating Doppler	digital	24	3	1
Scientific, Satellite				
Transponder				
Phase lock indication	dc to 10	1	3	1/10
AGC	dc to 10	8	3	1/100
Transmitter power out	dc to 10	8	3	1/100
Housekeeping, Satellite				
Transponder				
Battery voltage/ current	dc	7	2	1/100
Satellite temperature	dc -0.1	12	1	1/10

Parameter	Bandwidth, Hz	Word Length, bits	Channels	Sampling rate, sps
Housekeeping, Tether				
Subsystem				
Tether tension	dc - 10	7	1	1/10
Range of tether end	dc - 100	10	1	1
Azimuth	dc - 100	10	1	1
Elevation	dc - 100	10	1	1

It may be seen from the low sampling rates required that most of these data can be clocked out onto very few recorder channels, possibly only two.

5.9.8 Development Status

5.9.8.1 Forerunner instruments.- The Doppler Tracking Experiment MA089 flown on the ASTP mission may be the basis for the design on this instrument.

5.9.8.2 Problems.- Design problems will be inherent in the proposed tether system. For more details of the feasibility of this system, see the preliminary report "Shuttle-Borne Skyhook: A New Tool for Low-Orbital-Altitude Research," Smithsonian Institution Astrophysical Observatory, September 1974.

The design and manufacturing requirements have not been determined. Operational problems are not major since the transmitter and receiver antennas are within the state-of-the-art. It is suggested that a third very high frequency be added which will have very slight Faraday rotation in comparison to the specified frequencies.

5.10 COHERENT SCATTER RADAR - INSTRUMENT 410

5.10.1 Objective

This instrument will scatter radar beams from coherent wave structures in the ambient plasma to study wave modes and levels associated

with natural and artifical instabilities created by wave or particle injection into the medium. Information gathered by this instrument will be useful in determining properties of the ambient medium and will also yield information as to the nature of the instabilities producing the waves in the medium.

5.10.2 General Description

5.10.2.1 Location.- This instrument will be mounted on the pallet.

5.10.2.2 Configuration.- This radar system will transmit pulses of energy at several discrete frequencies, receiving backscattered data from density fluctuations associated with nonthermal levels of wave activity resulting from natural or induced instabilities in the medium. The coherent backscattering associated with these phenonena will be of much higher amplitude than the returned energy from incoherent backscattering. Consequently, lower transmission power will be required for this instrument than for the Incoherent Scatter Radar Measurements (Instrument 406).

It has been proposed that this instrument share the 20-m dish antenna and the capacitor storage bank required for the Incoherent Scatter Radar Measurements (Instrument 406). Four discrete transmitting frequencies between 20 MHz and 500 MHz will be used. Below 100 MHz, the 20-m dish will no longer be efficient and an antenna array of some sort will be needed. Above that frequency, multiple feeds can be included that can use the 20-m dish efficiently.

Four major assemblies are required: (1) antenna, (2) transmitter/receiver units (one for each frequency), (3) energy storage capacitor bank having a capacity of 1 MJ, and (4) autocorrelation and real-time analysis electronics.

The antenna and capacitor bank have been discussed in the Incoherent Scatter Radar Measurements (Instrument 406) description and will not be repeated here. Additional antenna arrays will be required below 100 MHz, but should not take up much more additional space over the 20-m dish, which will be used at higher frequencies.

5.10.2.3 Specifications.- The specifications applicable to this instrument are discussed in the following subparagraphs.

5.10.2.3.1 Frequency: This instrument will operate at four discrete frequencies between 20 MHz and 500 MHz. Bandwidth is to be specified, but an analog tape recorder with greater than 5 MHz bandwidth will be required to record return signals.

5.10.2.3.2 Resolution: The resolution requirements are TBD.

5.10.2.3.3 Sensitivity: The antenna (20-m diameter) gain will vary with frequency. At 100 MHz, gain will only be 23 dB; while at 400 MHz, gain will be about 35 dB. Below 100 MHz, the antenna will have to be an array designed for the specific frequency. The receiver sensitivity will be dependent on the expected return signal strength and frequency.

5.10.2.3.4 Field of view: The field of view is not specified, but will probably be around 3° beamwidth to the first nulls of the main beam at the shorter wavelengths. The geometric accuracy to which the 20-m dish can be deployed and maintained will have a definite effect on the field of view and resolution.

5.10.2.3.5 Data collection rate: The data collection rate cannot be specified as it is dependent on the transmitting repetition frequency which will be limited by power availability. The data measurement bit rate will be sampled at 16,000 or 2000 8-bit words. This will yield 200 autocorrelation coefficients. It is assumed, but not specified, that the above bit rate will be per channel basis.

5.10.2.3.6 Power: Antenna movement will require 100 W. Transmitter power will be 100-kW peak at a 2-kW average. Receiver and correlation electronics power has not been specified, so they are assumed to use another 100 W.

5.10.2.3.7 Physical dimensions: The physical characteristics of size and weight for the instrument are as follows:

a. Antenna (shared with Instrument 406) - 20-m diameter and 450 kg.

b. Transmitter/receiver - 1 cu m for all four T/R units and 140 kg for all four units.

c. Energy storage system (shared with Instrument 406) - 3 cu m and 4536 kg.

5.10.3 Operation

5.10.3.1 Pointing requirements.- The antenna should be able to point in any direction to an accuracy of 0.3° by a combination of antenna steering and vehicle attitude changes.

5.10.3.2 Stabilization.- Because of the pulse repetition rate, vehicle stability should not be limited. Pointing requirements will be more important. The antenna should be held steady for short time periods so that data can be integrated.

5.10.3.3 Timeline.- The timeline requirements have yet to be determined.

5.10.3.4 Constraints.- One primary constraint will be how fast the energy storage capacitors can be recharged. This will establish the instrument pulse repetition frequency for specific power outputs. Heat dissipation from the transmitter and energy storage bank may also limit total transmission time.

This instrument will have a power output of 100 kW at discrete frequencies between 20 and 500 MHz. The high-frequency energy will be focused or collimated by a large parabolic dish reflector and can be dangerous. An energy level of 10 mW/sq cm is considered to be within tolerance, and it is estimated that a safe level will be reached after a distance of approximately 50 m in front of the antenna. Because of antenna size and other instrument requirements, it is not expected that this will be a flight problem, but precautions should be taken during ground testing.

5.10.4 Checkout and Test

The checkout and test requirements have yet to be determined.

5.10.5 Controls

No controls have been specified. As this instrument's operation may be time-shared (internally) with Instrument 406, the controls should include:

a. Antenna deployment

b. Power up

c. Transmit and receive modes

d. Display and housekeeping control

e. Variation of mode of data processing

5.10.6 Displays

The following items will be displayed:

a. Return signal strength as a function of delay, for each of the four frequencies.

b. Spectra of the returned signal at 10 ranges.

5.10.7 Data

5.10.7.1 Scientific.- For each group to transmitted pulses, there will be 200 autocorrelation coefficients generated at each of the four frequencies selected. The bit rate for the raw data should be about 16 kHz.

5.10.7.2 Housekeeping.- Housekeeping data requirements have not been specified, but should include some pointing coordinates, power supply, and transmitter temperatures. The instrument will require the use of a broadband (greater than 5 MHz) tape recorder (video) and possible use of the onboard computer for real-time data analyses.

5.10.8 Development Status

5.10.8.1 Forerunner instruments.- No forerunner instruments have been specified.

5.10.8.2 Problems.- Anticipated problems with this instrument are as follows:

5.10.8.2.1 Design and manufacturing: The design problems will include:

a. Design of deployable 20-m diameter dish reflector combined with lower frequency antenna arrays. Antenna weight can be reduced considerably by using different materials and methods of deployment.

b. Low vehicle EMI between 20 MHz and 500 MHz.

c. Antenna alignment to Orbiter coordinates.

d. Miniaturization of electronics.

e. Shielding of electronics.

5.10.8.2.2 Operational problems: Operational problems will include:

a. Low vehicle EMI requirements between 20 MHz to 500 MHz.

b. Antenna inertia during attitude and pointing adjustments.

c. Heat dissipation from transmitter and power storage unit.

d. Antenna distortion due to thermal gradients caused by sunlight.

5.11 EXTREME LOW FREQUENCY (ELF)/VERY LOW FREQUENCY (VLF) RECEIVER - INSTRUMENT 411

5.11.1 Objective

This instrument will measure the electric and magnetic field components of electrostatic and electromagnetic waves in the frequency range from 100 Hz to 30 kHz.

5.11.2 General Description

5.11.2.1 Location.- This instrument will be mounted on a boom.

5.11.2.2 Configuration.- This instrument will consist of an antenna subassembly, six receivers, and data conditioning electronics.

The antenna subassembly will be boom mounted (no length specified) or on a subsatellite, if EMI requirements cannot be met in close proximity to the Orbiter. It will consist of three orthogonal loop antennas having an effective area of 100 sq m at 1 kHz and a set of orthogonal dipoles each 3-m tip-to-tip. The stored antenna subassembly will be sized by the orthogonal loops, and the extended subassembly will be sized by the dipoles.

Also on the boom will be the electronics packages containing the receiver preamplifiers. The data conditioning electronics will be pallet mounted. See figure 5-11 for the overall concept.

The electric and magnetic field components will be telemetered in two wideband frequency ranges, 100 to 600 Hz and 500 Hz to 30 kHz. Narrowband step-frequency receivers will also monitor these bands and transmit signal amplitude from the antennas. If boom mounted, all signal transmission will be hard wired. If subsatellite mounted, telemetry system will be added.

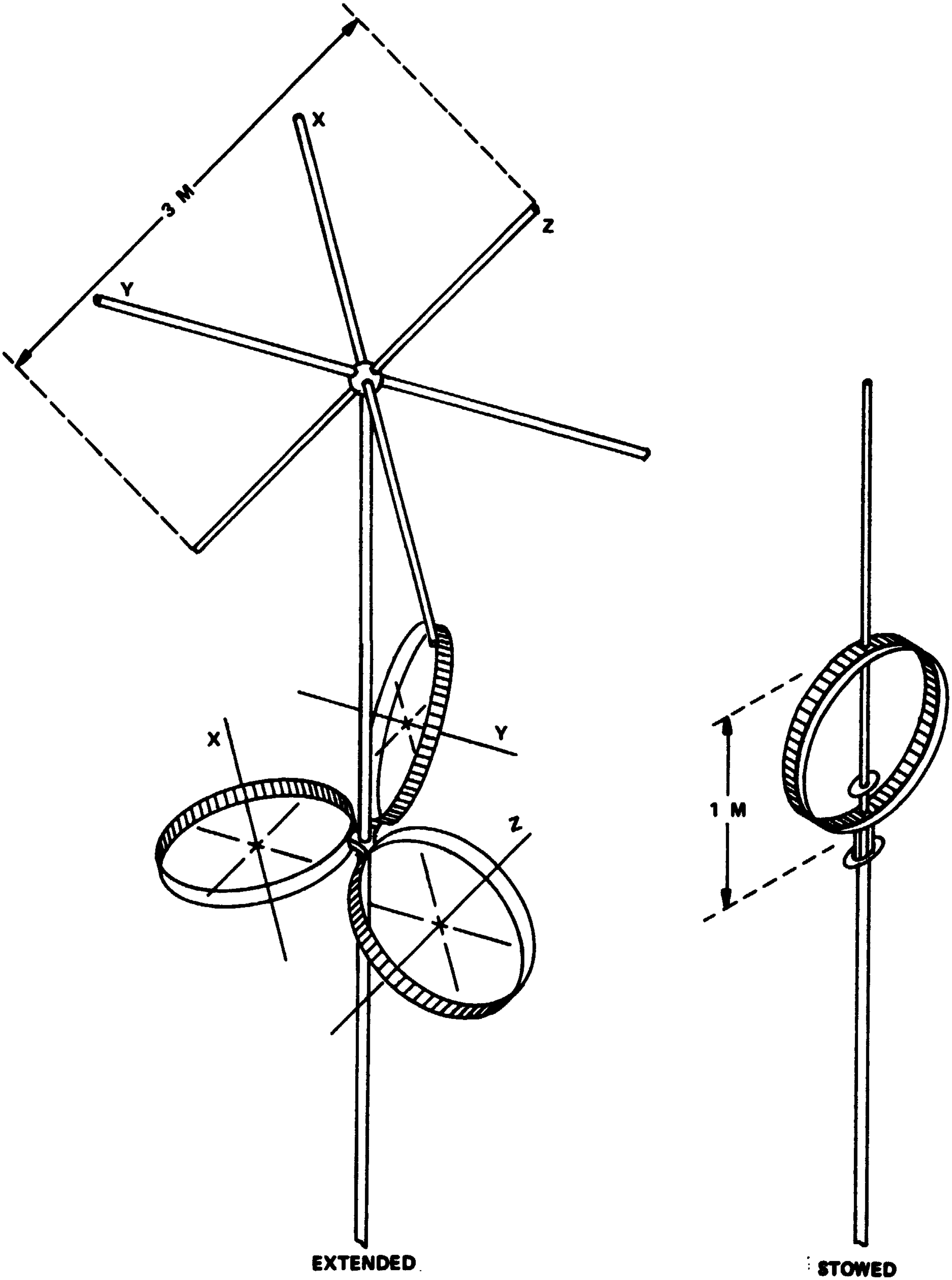

Figure 5-11.- Antenna configuration.

5.11.2.3 Specifications.- The specifications applicable to this instrument are as follows.

5.11.2.3.1 Frequency: This instrument will operate over a range of 100 Hz to 30 kHz. This frequency will be monitored in two ranges, 100 to 600 Hz and 500 Hz to 300 kHz. Narrowband receivers, having a bandwidth (not yet determined), will sweep the operating range.

5.11.2.3.2 Sensitivity: The sensitivity is yet to be determined. Ambient field interference will be specified at less than 0.01 $\mu V/m\ Hz^{1/2}$ for E-fields and less than $3 \times 10^{-3}\ \gamma/Hz^{1/2}$ for B-fields.

5.11.2.3.3 Data collection rate: The data collection rate will be 10 sps per parameter.

5.11.2.3.4 Power: Total system power will be 18 W at 20 Vdc. This will be separated out between the data conditioning electronics, 15 W, and the preamplifiers, 3 W.

5.11.2.3.5 Physical dimensions: The physical characteristics of size and weight are as follows:

a. Pallet-mounted data conditioning subassembly - 0.3 x 0.3 x 0.2 m (12 x 12 x 8 in.), 0.018 cu m and 12 kg.

b. Boom-mounted preamplifiers - 0.5 x 0.15 x 0.1 m (6 x 6 x 4 in), 0.002 cu m and 1.5 kg.

c. Antenna subassembly - 0.1 cu m (stored) and 3 x 3 x 3 m or 27 cu m (extended) and 7 kg.

5.11.2.3.6 Other: EMI contamination requirements will dictate whether the antennas be boom or subsatellite mounted. Boom length required has not been determined.

5.11.3 Operation

5.11.3.1 Pointing requirements.- This instrument will require that pointing accuracy be to 1°, with Orbiter rates limited to less than 1 rps. Orbiter attitude should be known to 0.1°. Since the receiving antennas will be boom mounted, the above accuracies may be difficult to achieve or to relate to pointing.

5.11.3.2 Stabilization and tracking requirements.- No stabilization and tracking requirements are applicable to this instrument.

5.11.3.3 Timeline.- This instrument's operation will be essentially continuous after deployment. It will be used as required for other active experiments that could use information generated from the data.

5.11.3.4 Constraints.- The major constraint will be the low EMI requirements of less than 0.01 $\mu V/m\ Hz^{1/2}$ radiated E-fields and less than $3 \times 10^{-3}\ \gamma/Hz^{1/2}$ for radiated B-fields. If these constraints cannot be satisfied, a subsatellite, with its required ancillary hardware (power supplies, telemetry, etc.) will be needed.

5.11.4 Checkout and Test

The checkout and test requirements have not yet been determined.

5.11.5 Controls

The following functions will be controllable, either manually or by computer:

a. Power up controls

    1. Electric field

    2. Magnetic field

b. Boom deployment

c. Antenna dipole deployment

d. Choice of field components (six total)

    1. Electric field - (three each; X, Y, and Z)

    2. Magnetic field - (three each; X, Y, and Z)

5.11.6 Displays

The following displays will be required:

a. Ampligram (magnetic field amplitude) spectrum on CRT

b. Electric field spectrum on CRT

c. Orbiter and subsatellite (if used) range and geometry with respect to the geomagnetic field. This can be displayed or printed out.

d. Plasma density and composition. Density can be displayed as a number, but composition will require a spectrum display and will have to be done on a CRT.

5.11.7 Data

There will be six narrowband swept-frequency receivers (one for each antenna), three of which will amplify ELF and VLF magnetic field data and three which will amplify ELF and VLF electric field data. All data will be transmitted to the data conditioning electronics as analog data of ±2.5 V. The electronics will provide the data as follows.

Parameter	Type	Bandwidth, Hz	Amplitude, V	Word Length, bits	Channels Required	Sampling rate, sps
Broadband amplitude	Analog	600	0-5	12	4	10
Narrowband amplitude	Analog	TBD	0-5	12	12	10
Housekeeping status	Analog	TBD	0-5	8	6	1
Command verification	Analog	-	0-5	1	10	1

The housekeeping status and command verification can be combined by utilizing a doubled sampling rate.

5.11.8 Development Status

5.11.8.1 Forerunner instruments.- No forerunner instruments have been specified.

5.11.8.2 Problems.- Anticipated problems are discussed in the following subparagraphs.

5.11.8.2.1 Design and manufacturing: No design or manufacturing problems are specified or foreseen. Antenna and electronics design will be within the state-of-the-art.

5.11.8.2.2 Operational: EMI problems have already been discussed in the Constraints paragraph (5.11.3.4) of this instrument description.

5.12 VLF QUADRUPOLE PROBE FOR STUDY OF LOWER HYBRID MODES - INSTRUMENT 415

5.12.1 Objective

This instrument will study the electrostatic wave propagation near the lower hybrid frequency and will develop an ac method for measuring dc fields precisely.

5.12.2 General Description

5.12.2.1 Location.- The instrument sensors will be mounted on the boom, and the electronics will be mounted on the pallet.

5.12.2.2 Configuration.- This instrument will consist of the sensor package and an electronics subsystem. The electronics can be further broken down to a stepped-frequency transmitter and a superhetrodyne receiver, which together will form a transfer function meter.

The sensor package will consist of four spherical electrodes about 2-cm in diameter, mounted and connected to form two parallel dipoles having a separation of 4 m and a distance of 4 m between pairs of spheres. The square formed will be installed at the end of a 20- to 50-m boom and oriented perpendicular to the earth's magnetic flux. One pair of spheres will be used for transmitting, the other for receiving. Thus there will be four possible modes of operation. See figure 5-12 for the overall sensor concept.

The transfer function meter will be used to measure the transfer impedance between the two dipoles as a function of frequency between 20 Hz and 20 kHz. This impedance will peak at the lower hybrid resonance (LHR) and will show static wave propagation at slightly higher frequencies. The LHR can be used to calculate the mean ion mass of the plasma. The signal levels applied to the transmitting antenna will be less than 1 V.

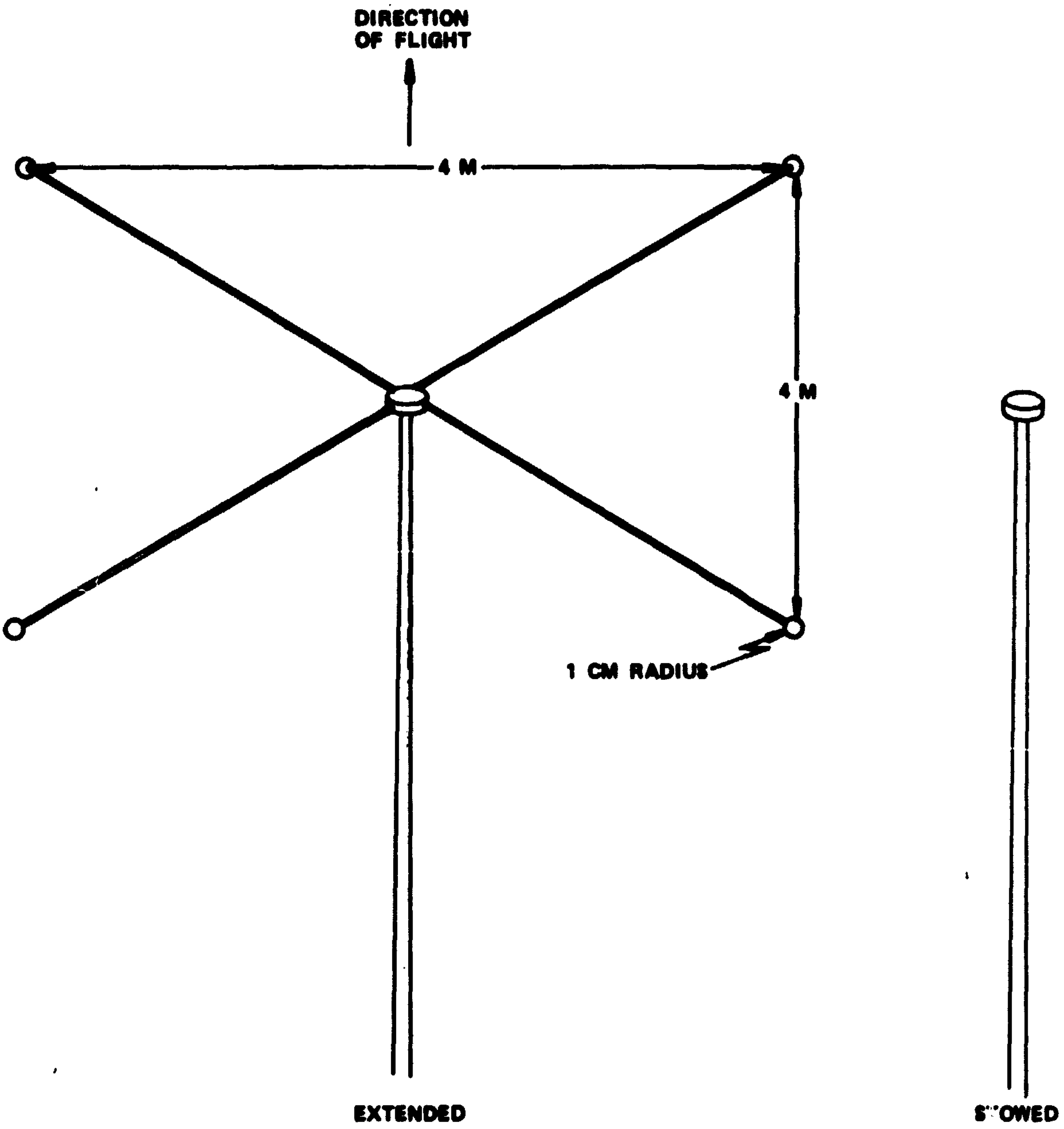

Figure 5-12.- Antenna configuration.

By compassing measurements made with the four possible antenna combinations, the two perpendicular components of the dc electric field can be determined. The transfer function will show the effects of plasma movement in the plane perpendicular to the magnetic field. This movement will be caused by dc electric fields in the Orbiter coordinate system.

Magnetometers near the sensors will probably be required for sensor orientation and their outputs used in data reduction.

5.12.2.3 <u>Specifications</u>.- The specifications applicable to this instrument are discussed in the following subparagraphs.

5.12.2.3.1 Frequency: The transfer function meter will operate in a stepped-frequency mode (transmit and receive) in the range 20 Hz to 20 kHz.

5.12.2.3.2 Sensitivity: Magnetic perturbations should be less than 1 percent of the earth's field or about 5×10^{-3} gauss. To achieve this sensitivity may require subsatellite installation.

5.12.2.3.3 Data collection rate: Scientific data will be sampled at 256 samples per second per parameter.

5.12.2.3.4 Power: The transfer function meter will use 100 W of power at 20 Vdc.

5.12.2.3.5 Physical dimensions: The physical characteristics of size and weight for this instrument are as follows:

a. Sensor package (deployed) - four 2-cm diam spheres will form a 4-m square and 4 kg.

b. Transfer function meter - 0.1 cu m and 150 kg.

5.12.2.3.6 Other: The sensor package, four spherical electrodes spaced to form a 4-m square, are to be boom mounted in an effort to minimize electric and magnetic field interference.

5.12.3 Operation

5.12.3.1 <u>Pointing requirements</u>.- The pointing accuracy required in pitch, roll, and yaw will be 1°.

5.12.3.2 Stabilization.- Allowable rates in pitch, roll, and yaw after positioning is established will be 0.01 deg/sec. Boom motion can create a VLF background and should be studied.

5.12.3.3 Attitude.- The Orbiter attitude, as it relates to sensor orientation, will be known to 0.1°.

5.12.3.4 Timeline.- Data takes, after deployment and sensor positioning, will range from a minimum of 10 minutes to a maximum of 5 hours. This flexibility will allow complementary operation with other instruments, or the instrument will be turned off when other instruments can cause EMI problems.

5.12.3.5 Constraints.- Magnetic perturbation should be less than 1 percent of the earth's magnetic field at the sensors.

5.12.4 Checkout and Test

The checkout and test requirements have yet to be determined.

5.12.5 Controls

The following parameters will be under manual control:

a. Power up

b. Antenna status (four possible states)

c. Transfer function display

The following items can be manually or computer controlled:

a. Choice of antenna combinations used

b. Choice of frequency sweep range and rate (which will then be computer controlled)

The parameters to be computer controlled are:

a. Antenna combinations used (four possibilities)

b. Programmed stepping of measurement frequency

5.12.6 Displays

The requirements document states that transfer function versus frequency and the antenna status be put on a CRT display. This will only be necessary if a scientist is onboard during the mission. No improvement in tuning or fine "tweaking" will be done to the controls because of any information derived from the required displays. The information can be telemetered for ground display and processing.

5.12.7 Data

Six scientific and four housekeeping parameters are to be measured. Although the housekeeping parameters are specified in the requirements document as analog, digital may also be used. Therefore, all parameters called out on the following table will be digital.

Parameter	Word length, bits	Sampling rate, sps
SCIENTIFIC		
Transmitted VLF current	12	256
Transmitted VLF frequency	12	256
Received VLF amplitude	16	256
Received VLF phase	12	256
Dc antenna 1 voltage (0 to 1 V, 1 mV accuracy)	10	256
Dc antenna 2 voltage	10	256
HOUSEKEEPING		
Temperature, sphere 1	9	1
Temperature, sphere 2	9	1
Temperature, sphere 3	9	1
Temperature, sphere 4	9	1

5.12.8 Development Status

5.12.8.1 Forerunner instruments.- Probes of this type have been successfully flown in two French rocket experiments. (Reference an article by Beghin and Debrie, Journal of Plasma Physics, vol. 8, 1972, pp. 287.)

5.12.8.2 Problems.- Problems associated with the development of this instrument are as follows.

5.12.8.2.1 Design and manufacturing: The design and manufacture of this hardware should be within the state-of-the-art.

5.12.8.2.2 Operational: After power up, operation will be simplified by computer control so the only operational problems foreseen will be associated with EMI.

5.13 SIX COMPONENT MEASUREMENTS OF RANDOM VLF WAVE FIELDS - INSTRUMENT 416

5.13.1 Objective

This instrument will determine the wave distribution functions for weakly turbulent electromagnetic fields in space in the frequency range 100 Hz to 20 kHz.

5.13.2 General Description

5.13.2.1 Location.- This instrument will be mounted on the boom.

5.13.2.2 Configuration.- This instrument will measure the wave distribution functions (wave energy distribution versus frequency and wave-normal direction) using orthogonal electric dipoles and orthogonal ferrite-cored loops. The sensor package, consisting of the electric dipoles and magnetic loops, will be mounted on the 20- to 50-m boom; orthogonally oriented magnetometers will be mounted on the same boom. The stored dimensions will depend on the design used. Deployed, the dipoles will be oriented orthogonally to each other. The dipoles can be mounted in a cross configuration, while the coils can be mounted end to end in the three axes.

The electronics are to be installed on a pallet. The electronics will consist of: (1) a six-channel receiver, (2) a frequency/time spectograph, and (3) a six-channel spectrum analyzer. See figure 5-13 for the sensor concept.

Electric and magnetic field signals will be sensed by the antennas and amplified to a usable voltage by six separate receivers. The six signals will be transmitted to a real-time spectrum analyzer which will evaluate the 6 autospectra and the 15 cross-spectra, each consisting of a cospectrum and a quadrature spectrum. These 36 spectra will be fed to the Orbiter computer for real-time evaluation of the distribution function (if feasible) or for storage.

By observing a real-time presentation of frequency/time spectrogram of a single component, an operator can see and identify random phenomena when they appear and choose appropriate control settings on the spectrum analyzer.

5.13.2.3 Specifications.-

5.13.2.3.1 Frequency: This instrument will operate on the frequency range 0.1 to 20 kHz. It will operate as a receiver (passive) only.

5.13.2.3.2 Resolution/Sensitivity: The resolution/sensitivity of this instrument has yet to be determined.

5.13.2.3.3 Data collection rate: The data collection rate will be 1024 sps per component.

5.13.2.3.4 Power:

Receivers: 50 W, 28 Vdc

Spectrograph: 100 W

Spectrum analyzer: 250 W

Total required: 400 W

5.13.2.3.5 Physical dimensions: The physical characteristics of size and weight of this instrument are as follows.

a. Sensor package with electric dipoles - 4 m tip-to-tip (deployed), (stored size to be determined) and 8 kg.

b. Magnetometers - 0.25 x 0.04 x 0.04 m and 2 kg.

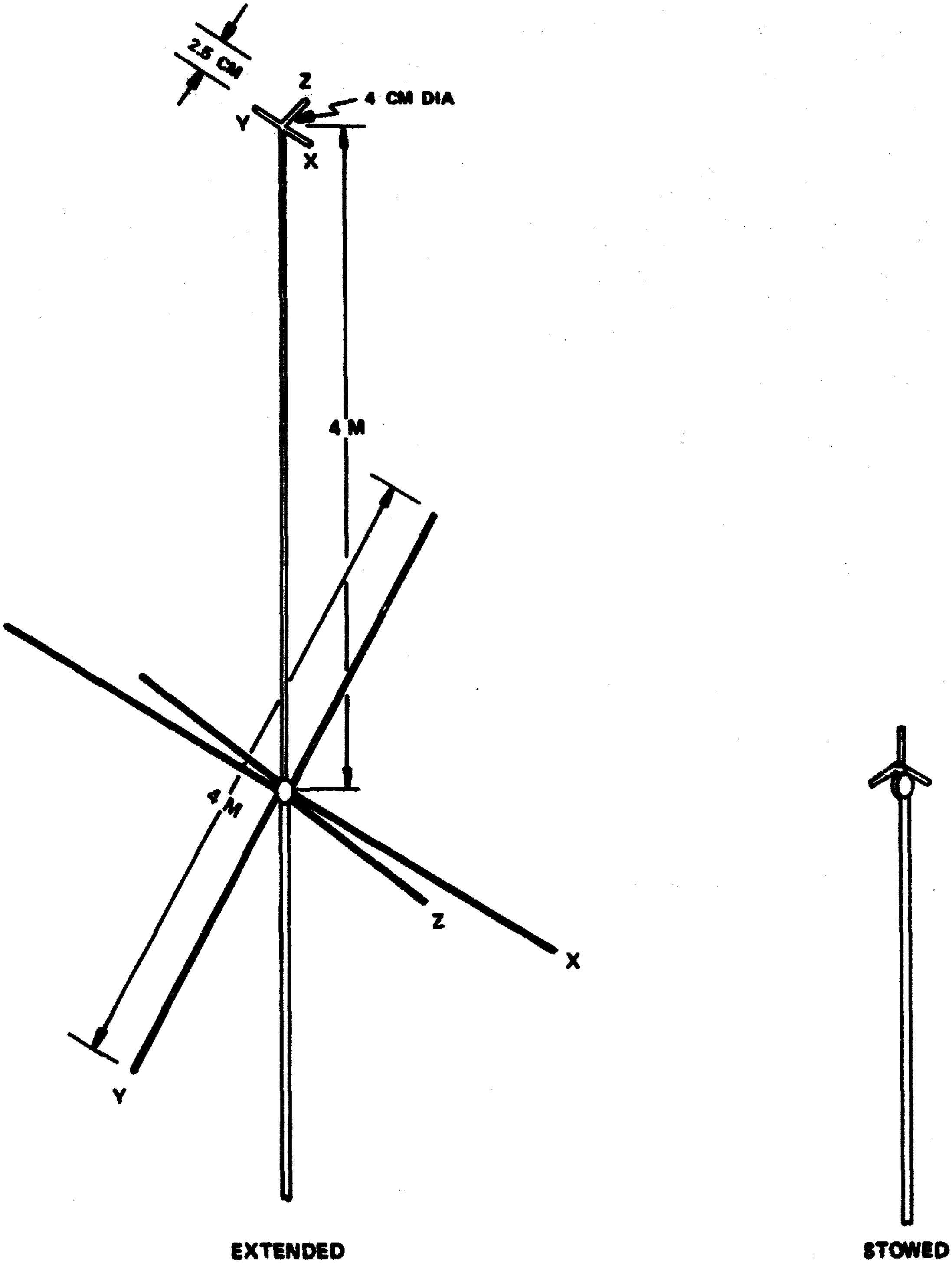

Figure 5-13.- Antenna configuration.

5.13.3 Operation

5.13.3.1 Pointing requirements.- Orbiter pointing accuracy will be 1° in each axis for this instrument. Orbiter attitude requirement will be 0.5° in relation to sensor orientation. These accuracies may be difficult to achieve with a boom-mounted instrument.

5.13.3.2 Stabilization.- Allowable Orbiter rates in pitch, roll, and yaw will be 0.1 deg/sec.

5.13.3.3 Timeline.- After sensor deployment, the operational period will vary from a minimum of 10 minutes to a maximum of 12 hours.

5.13.3.4 Constraints.- If the EMI requirements (as specified by the Wave Phenomena Section of the AMPS Working Group) cannot be met using the 50-m boom, the experiment will have to be transferred to a subsatellite. The analyzing electronics will remain on the Orbiter. This will complicate data reduction, since corrections will have to be made for attitude changes of the subsatellite. The experiment may require active onboard participation of the scientist.

5.13.4 Checkout and Test

The checkout and test requirements have yet to be determined.

5.13.5 Controls

The following controls will be required if real-time control adjustments cannot be made.

a. Sensor package deployment

b. On/off, receiver, spectrum analyzer

c. Display housekeeping, i.e., temperature, voltage, current to receiver and spectrum analyzer

If control adjustments will be made, the following additional controls will be needed:

a. Spectrograph on/off

b. Spectrograph display

1. Vertical axis

2. Horizontal axis

3. Brightness

4. Choice of channel (36)

c. Receiver characteristics (6 receivers)

1. Gain

2. Bandwidth

d. Spectrum analyzer characteristics

1. Center frequency

2. Bandwidth

3. Frequency resolution

4. Integration time

Other controls may be needed, but have not been specified. The Orbiter computer will be required if real-time evaluation of the data is done and the spectrum analyzer is to be adjusted.

5.13.6 Displays

If control adjustments cannot be made in real time, the display will consist of hardware status as described in the first portion of the paragraph 5.13.5. If adjustments are possible, a CRT display of the frequency/time spectrogram will also be required. This will be a display of X-axis, time, Y-axis, frequency, spot brightness, and spectral amplitude.

5.13.7 Data

5.13.7.1 Scientific.- There will be an occasional requirement for wideband data recording, separate from the continuous digital recording. The wideband data will be recorded analog and will consist of recording one E-field component and one B-field component. These data will be recorded in analog format with a bandwidth of 0 to 10 kHz, an amplitude of ±1 V with an accuracy of 1 percent (20 mV).

If data are displayed and control adjustments can be made on the spectrum analyzer in real time, it will be desirable that a spectrum output be recorded at the same time that it is displayed on the CRT. These data will be recorded in analog, bandwidth 0 to 5 kHz, amplitude of ±1 V, and with an accuracy of 1 percent (20 mV).

All 36 outputs of the spectrum analyzer are to be recorded as digital 8-bit words at 1024 words/sec.

5.13.7.2 Housekeeping.- No housekeeping functions have been specified to be recorded. Such parameters as temperature, voltage, current to the various electronic components, and Orbiter attitude will be required.

5.13.8 Development Status

5.13.8.1 Forerunner instruments.- No instruments are referenced in the functional requirements document, but E-field and B-field measurements have been made separately on many sounding and orbital experiments. An instrument of this type, that combines the two types of field measurements and processes the data in real time through a spectrum analyzer for data correlation, is probably unique.

5.13.8.2 Problems.- The problems anticipated with the development of this instrument are discussed in the following subparagraphs.

5.13.8.2.1 Design and manufacturing: The design and manufacture of this instrument should pose no unusual problems. Hardware similar to the proposed instrument has been constructed and used previously. If real-time adjustments to the controls cannot be done, allowances in the design will have to be made so that the instrument can identify random phenomena when they appear and make its own internal adjustments.

5.13.8.2.2 Operational: There is a possibility that the EMI environment, even on the 50-m boom, may not be compatible to this instrument's operation. If this occurs, the sensors and receivers, along with a telemetry system, will have to be installed on a subsatellite.

5.14 RESONANCE CONE - INSTRUMENT 417

5.14.1 Objective

This instrument will develop or utilize resonance cone measurements for diagnostics of the local plasma.

5.14.2 General Description

5.14.2.1 <u>Location</u>.- The instrument's sensors will be mounted on the boom and the electronics mounted on the pallet.

5.14.2.2 <u>Configuration</u>.- This experiment will be based on the observation of "oblique" or "cone" resonances that occur in certain frequency bands. The resonances can be related to electron temperature which in turn can be related to the plasma density. The resonances will be observed by propagating RF signals between two small antennas (much smaller than the distance between them) over distances of 100 or more Debye lengths (typically 1 to 2 m) in directions that make an oblique angle to the magnetic field. Debye length is based on the electric dipole moment between charged particles.

The resonances can be observed by two methods. The frequency transmitted can be fixed while the antenna is rotated in the magnetic field. This method has been used in the past on spinning rockets and satellites. Alternately, the antenna can remain stationary in relation to the field, and the frequency can be varied through the range that will contain the resonance. The proposed instrument will be capable of operating in either mode.

The equipment required will consist of two subassemblies: (1) the sensor array, which will be boom mounted to minimize EMI problems and (2) the electronics, which will be a transmitter and receiver, pallet mounted and coupled in such a way that they are essentially a transfer function meter.

The sensor array will consist of separate transmitting and receiving antennas mounted at each end of a 2-m boom. The boom will be rotatable about its center at about 60 to 120 rpm. The antennas can also be stopped at any given azimuth angle for a swept frequency mode of operation. The antennas will be connected to the electronics which will operate as a transfer function meter. See figure 5-14 for the overall concept.

5.14.2.3 <u>Specifications</u>.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.14.2.3.1 Frequency: The instrument will transmit at discrete frequencies or do a frequency sweep between 10 kHz and 10 MHz.

5.14.2.3.2 Resolution and Sensitivity: The resolution and sensitivity of this instrument have not yet been determined.

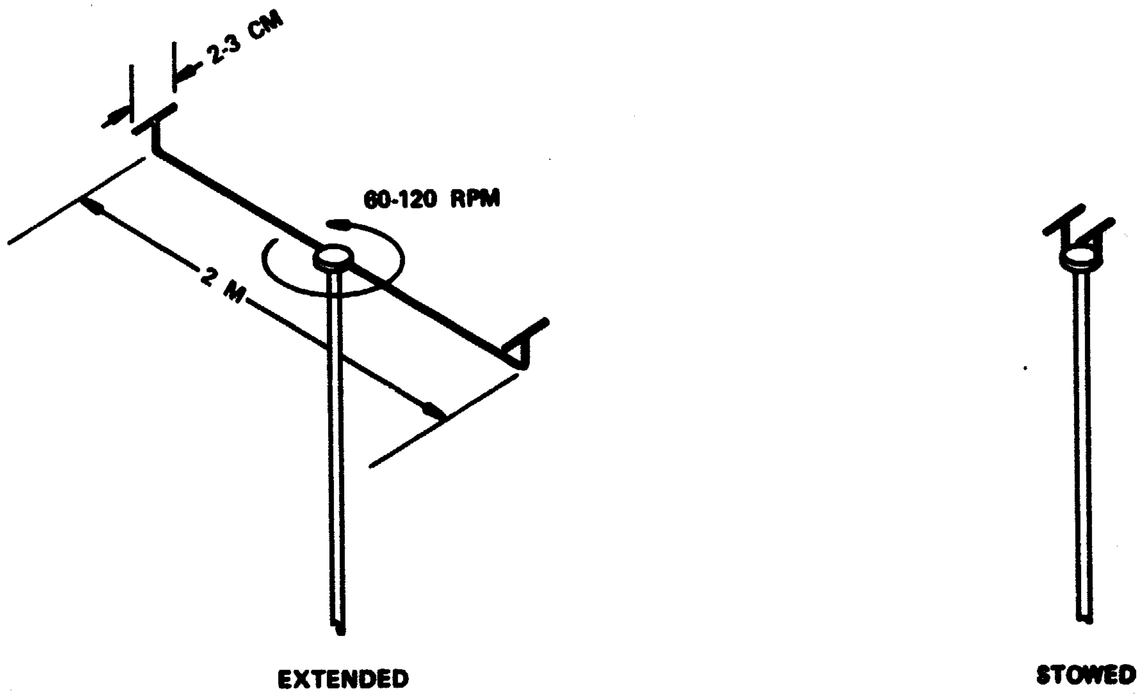

Figure 5-14.- Antenna configuration.

5.14.2.3.3 Data collection rate: The instrument will sample scientific data at 2024 sps.

5.14.2.3.4 Power: Total average power required will be 80 W with a maximum of 100 W. The electronics package will use 50 W of the total. The spin platform will use 30 W average, 50 W maximum depending on its operating mode.

5.14.2.3.5 Physical dimensions: The physical characteristics of size and weight of this instrument are as follows:

a. Sensor array - 2 x 0.1 x 0.1 m and 0.5 kg.

b. Spin platform - 0.2 x 0.2 x 0.25 m and 5 kg.

c. Electronics - 0.5 x 0.5 x 0.2 m and 50 kg.

5.14.2.3.6 Other: This instrument may require the use of a three-axis magnetometer to give magnetic field strength and direction. If used, its output will be added to the housekeeping data.

5.14.3 Operation

5.14.3.1 Pointing requirements.- Pointing requirements for this instrument will be 1° in pitch, roll, and yaw.

5.14.3.2 Stabilization.- It will be desirable that the Orbiter rates in pitch, roll, and yaw not be greater than 0.01 deg/sec. The Orbiter attitude in relation to sensor orientation should be known to 0.5°.

5.14.3.3 Timeline.- Operating periods will vary from a minimum of 10 minutes to a maximum of 3 hours. Standby periods will be typically 1 hour or longer.

5.14.3.4 Constraints.- If EMI levels as specified by the Wave Phenomena Section of the AMPS Working Group cannot be met, this instrument will have to be redesigned for subsatellite installation.

5.14.4 Checkout and Test

A full calibration of the antenna transfer function over the frequency range will have to be made. Also discrete frequencies versus angle to the magnetic field measurements will have to be taken. Variations in transfer function versus strength of magnetic field, signal

amplitude, antenna, and receiver gains will also be significant. The design and development phase will confirm checkout and test functions.

5.14.5 Controls

There will be two modes of operation with this instrument, constant frequency (CF), while varying the antenna angles with the magnetic field, and constant angle (CA), while varying the frequency. The following controls will be needed:

a. Antenna deployment

b. On/off of electronics

c. Antenna rotation, on/off (CF mode)

d. Antenna rotation, rate (CF mode)

e. Frequency selection, between 10 kHz and 10 MHz (CF mode)

f. Frequency selection, discrete or swept frequency

g. Antenna orientation (possibly a computer-controlled operation)

h. Computer control of transmitter frequency

5.14.6 Displays

The instrument will require CRT display of the resonance curve together with calibration status. If a real-time display is not done, as these data are not required for instrument tuning, the calibration information will have to be recorded as housekeeping data. Other display information will consist of control status.

5.14.7 Data

All the measurements will be digital.

Parameter	Word length, bits	Sampling rate, sps
Angle between antenna booms	12	8 (max)
Spin platform azimuth angle	12	64 (max)
Transmitted RF current	12	2024 (max)
Transmitted RF frequency	16	2024
Received RF amplitude	16	2024
Received RF phase	12	2024
Receiver gain	12	64
Housekeeping status	12	8

Housekeeping data will show the status of all the control parameters already mentioned along with possible magnetometer readings.

5.14.8 Development Status

5.14.8.1 Forerunner instruments.- This type of instrument has been installed and has performed successfully on a satellite and sounding rockets.

5.14.8.2 Problems.- Anticipated problems with this instrument are discussed in the following subparagraphs.

5.14.8.2.1 Design and manufacturing: No design or manufacturing problems are foreseen.

5.14.8.2.2 Operational: The hardware will be susceptible to EMI, and perturbations at the sensors should be less than 0.1 of the earth's field. If this requirement cannot be met, along with others specified by the Wave Phenomena Section of the AMPS Working Group, the instrument should be redesigned for subsatellite operation.

5.15 VERY LOW FREQUENCY (VLF) ANTENNAS AND TRANSMITTER - INSTRUMENT 418

5.15.1 Objective

This instrument will be a wave source for experiments in the extreme low frequency/very low frequency (ELF/VLF) range. The required frequency range will be 1 to 20 kHz. It may be desirable that this range be extended to a minimum of 0.3 kHz.

5.15.2 General Description

5.15.2.1 Location.- This instrument will be mounted on the pallet.

5.15.2.2 Configuration.- The frequency range may be extended to 100 kHz and a large (100 sq m area) loop antenna added. There will be no receiver or experiment directly associated with this instrument, although its operating parameters will be directly related to a number of experiments dealing with wave interaction and ionospheric refraction. Receivers may be subsatellite mounted, ground-based, or colocated on the Orbiter (if EMI requirements can be met).

The low-frequency transmitter will consist of fou subsystems:

a. Power amplifier

b. Impedance matching network

c. Antennas

d. Programmer, modulator, and frequency synthesizer - all feeding into the linear power amplifier

The power amplifier, matching network, and antenna will be pallet mounted. The antenna, variable length dipole with a maximum length of 300 m tip to tip, may require a stabilized platform to be mounted on the pallet. The programmer, modulator, and frequency synthesizer will be installed in the pressurized module.

A study is being made at this time as to the best way to build an impedance matching network for the required frequency range. Antenna length variations are not efficient or practical at these long wavelengths.

5.15.2.3 Specifications .- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.15.2.3.1 Frequency: The instrument will transmit in the range 1 to 20 kHz. It may be desirable to extend this range to 0.3 kHz.

5.15.2.3.2 Data collection rate: The data will be sampled once per second. The majority of this data will be for housekeeping and system status with some parameters to be used with received data.

5.15.2.3.3 Power: The instrument will require a total average power of 3 kW with a maximum of 3.5 kW. Most of this power will be used by the linear power amplifier. The programmer, modulator, and frequency synthesizer will take 15 W of 28 Vdc power.

5.15.2.3.4 Physical dimensions: The physical characteristics of size and weight for this instrument are as follows:

a. Power amplifier - 0.3 x 0.33 x 0.18 m, 0.02 cu m and 36 kg.

b. Matching network - TBD, 0.06 cu m and 96 kg.

c. Antenna (stored) - 0.15 x 0.2 x 0.4 m, 0.012 cu m and 10 kg.

d. Programmer, modulator, and synthesizer - 0.3 x 0.3 x 0.2 m, 0.018 cu m and 12 kg.

5.15.3 Operation

5.15.3.1 Pointing requirements.- The required Orbiter pointing accuracy in pitch, roll, and yaw will be ±1° in each axis.

5.15.3.2 Stabilization.- The stabilization requirements are yet to be determined.

5.15.3.3 Attitude.- The required attitude knowledge will be ±0.5° in each axis.

5.15.3.4 Timeline.- Orbital parameters and operational times will be dictated by the experiments that this instrument will support.

5.15.3.5 Constraints.- There will be no EMI constraints specified for this instrument as it is active only. The type of experiments accomplished and receivers used will impose constraints.

5.15.4 Checkout and Test

The checkout and test requirements are yet to be determined.

5.15.5 Controls

The following items will be manually controlled or, in some cases, may be programmed and computer controlled.

a. Power input

b. Frequency

c. Antenna length

d. Antenna tuning (impedance match)

System power up and antenna deployment will be manual operations.

5.15.6 Displays

The following display will be required to indicate system status:

a. System on/off

b. Antenna length

c. Primary power

d. Power output

e. Component temperatures (consisting of electronics and antenna temperatures)

f. Driving frequency and voltage

g. Power amplifier overload

5.15.7 Data

The parameters which follow will all be 0 to 5 V analog data converted to 8-bit digital. The data will be sampled each second.

Parameter	Channels	Words
<u>Power Amplifier</u>		
Supply current	24	
Output voltage	24	
Power amplifier temperature	4	
Housekeeping	4	
<u>Impedance Matching Network</u>		
Power reflected	10	
Antenna impedance	10	
Tuner impedance	4	
Housekeeping	-	10
<u>Antenna</u>		
Length	4	
Housekeeping and status	12	
<u>Programmer, Modulator, Synthesizer</u>		
Status	8	
Housekeeping	4	

5.15.8 Development Status

5.15.8.1 <u>Forerunner instruments</u>.- None are specified, but ionospheric sounding devices have used transmitters of this type.

5.15.8.2 Problems.- Problems associated with the development and use of this instrument follow.

5.15.8.2.1 Design and manufacturing: Existing technology can be used in designing and manufacturing the power amplifier, antennas and their associated deployment mechanism, programmer, modulator, and synthesizer. The antenna matching network will be the largest uncertainty because of lack of sufficient operating data on the nonlinear characteristics of the antenna impedance.

5.15.8.2.2 Operational: Because of the antenna length when fully deployed, Orbiter stabilization will be a problem.

5.16 PHOTOELECTRON/SECONDARY ELECTRON SPECTROMETER - INSTRUMENT 526

5.16.1 Objective

The electron spectrometer will measure the electron flux and energy in the energy range of 2 to 500 eV. This energy range will be above that of the Langmuir probe and less than that of the medium energy electron analyzer. Electrons of this energy will be produced by photoionization and are the primary source of ion and electron heating in the thermosphere and higher altitude regions. The angular distribution and net flows will be measured as well as the energy spectrum. In addition, auroral secondary electrons and accelerator produced electrons will be detected.

5.16.2 General Description

5.16.2.1 Location.- The instrument will be mounted on a boom or subsatellite.

5.16.2.2 Configuration.- A pair of detector heads will have their acceptance angles in opposite directions. This will have the advantage of permitting detection of electrons following the flux lines in opposite directions and measuring the net flow. The center of the acceptance field may be biased away from the Orbiter to avoid contamination.

Each head will consist of two concentric hemispherical conductors with a difference of potential applied.

The radii of the outer and inner hemispheres will be 2.5 and 3.2 cm. Electrons in a certain energy range will make a semicircular path between the hemispheres, which have voltages applied, and will be detected after

exiting on the other side by an electron multiplier. Energies above and below a certain range will strike one sphere or the other.

Apertures at the entrance and exit focal planes will serve as field stops. They will have zero equipotential surfaces to eliminate fringe fields. They will also determine the energy resolution.

An extra stop in front of everything else will limit the entrance angle.

A hole in the outer hemisphere, in line with the entrance, will divert high-energy particles without producing interfering photoelectrons. A strong positive potential applied at the entrance of the electron multiplier will exclude ions. In line with the multiplier will be a constant electron source which will provide calibration and permit monitoring of the degradation of the multiplier.

The electron spectrometer should be located in a nonsunlit portion of the spacecraft. No part of the spacecraft should be in the view of the acceptance angle. Also, the effect of spacecraft magnetic and electric fields should be minimized. Electric fields near the Orbiter will perturb the measured energies, so it will be necessary to use data from the Langmuir probe to interpret the data. Similarly data on the magnetic field must also be obtained.

5.16.2.3 Specifications.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.16.2.3.1 Energy range: The energy range for measurements will be from 2 to 500 eV, although some utility below 2 eV may exist.

5.16.2.3.2 Resolution: The resolution of energy will be $\Delta E/E = 2.5$ percent.

5.16.2.3.3 Sensitivity: Individual electrons will be detected. However, unless a sufficient number is within the acceptance angle and entrance aperture and has the proper energy range, the number of electrons detected during the integration time will be statistically meaningless. The area solid angle product will be 5×10^{-4} cm^2 sr, the detection efficiency 50 percent, the energy increment of 2.5 percent of the energy, and the integration time one sixty-fourth of a sec. From this, the minimum number of electrons per unit area per unit solid angle per electron volt can be calculated for any desired confidence level and summation over any number of scans.

5.16.2.3.4 Field of view: The field of view will be 9° x 20° with the 20° side parallel to the surface of the vehicle and 9° at right angles to it. This will give a large acceptance angle to obtain good sensitivity without viewing the vehicle.

5.16.2.3.5 Data collection rate: The data collection rate is described in paragraph 5.16.3.5 (Timeline).

5.16.2.3.6 Power: The average and maximum power will be 3 W at 28 V. The standby power will not be applicable because of the rapid warmup time which will allow data to be obtained as soon as the instrument is activated.

5.16.2.3.7 Physical dimensions: The physical dimensions of size and weight are:

a. Size: 0.25 x 0.25 x 0.25 m

b. Weight: 5 kg

5.16.3 Operation

5.16.3.1 Pointing requirements.- The pointing accuracy must be within 5° and the Orbiter attitude known within 5°.

5.16.3.2 Stabilization and tracking requirements.- The allowable Orbiter rate will be determined. It will not be critical and may not be applicable.

5.16.3.3 Timeline.- The voltage will be applied in discrete steps, each 2.5-percent greater than the other. Each voltage sweep will always consist of 64 steps. In the slow-scan mode, the scan will be made in 1 second, giving 64 data points. In the high-scan mode, 4 scans/second will be made, but the signal from four successive voltage steps will be added together; thus, the output data rate will be the same in both cases.

Three ranges will be used: Data range A will be 0 to 25 eV, B will be from 0 to 100 eV, and C will be from 0 to 500 eV. These will run in sequences, and five different sequences will be used.

The electron spectrometer will be used in conjunction with the accelerator and other atmospheric perturbing experiments. These sources may, and probably will be, located on another vehicle.

5.16.3.4 Constraints.- The electron spectrometer, because it can detect individual electrons, will be extremely sensitive to local electric fields and magnetic fields. Such fields can distort the energy of the electrons and their direction. It will be sensitive to particulate contamination since the material can give off spurious electrons, and solar radiation because this will produce photoelectrons. Therefore, if the electron spectrometer is located on the Orbiter, it can be used only for diagnostic purposes. It must be located on a subsatellite to make measurements of the electron population in the atmosphere.

The particular location on any vehicle is critical because of the interactions.

5.16.4 Checkout and Test

5.16.4.1 Boresighting requirements.- The 5° accuracy will require only a simple mechanical check.

5.16.4.2 Prelaunch checkout.- A complete check will not be feasible because a vacuum will be required. The electrical subsystems should be checked.

5.16.4.3 Preflight calibration.- None is required.

5.16.4.4 Inflight calibration.- Because of the capability of detecting individual electrons, the instrument will be partly self-calibrating.

The effect of cosmic radiation and other spurious signals will be determined by applying a negative voltage step as the first step in each scan. Thus, no electrons will be detected and a zero level will be established.

A sample of Ni^{63} will be located in line with the multiplier for calibration. As the multiplier degrades, the calibration signal will become weaker, and the voltage applied to the multiplier will be increased. Eight steps will be available.

An 8-second deflection voltage measurement mode may be initiated. The data will appear in the apparent format of the scientific data as far as recording occurs. The A, B, and C voltages will be measured (by the instrument) with a digitizing error of 1.5 percent, 0.4 percent, and 0.08 percent of full scale, respectively.

5.16.5 Controls

The following controls will be required:

a. On/off for sensor head 1

b. On/off for sensor head 2

c. Mode command:

	Bits Required
State of high voltage 1 (8 voltages)	3
State of high voltage 2 (8 voltages)	3
Sweep rate (fast or slow)	1
Sweep mode (5 combinations)	3
Heads sampled (1, 2, 1 and 2)	2
Total	12

d. Deflection voltage measurement mode command (called "calibration" in references)

5.16.6 Displays

The display will be on a scope and will consist of either the number of counts versus energy in real time or these values integrated (improving the statistics) by the onboard microprocessor. The latter will be better unless the count is unusually high. Also, if two lights are on, both heads will be operating.

5.16.7 Data

5.16.7.1 Scientific.- At 64 sps, 6-bits per sample and two heads, the bit rate will be 768 bps on the Atmosphere Explorer C design. This will be converted to 8-bit words before output. If the electron counts are much higher due to Orbiter contamination, a greater bit rate may be required.

5.16.7.2 Housekeeping.- The following data will be sent every 4 seconds via a 16-bit word: all of the command data, which will require 15-bits, plus a deflection voltage measurement enable indicator.

The following six analog +5 V functions will be recorded every 8 seconds:

a. Voltage measurement

b. Sensor temperatures (heads 1 and 2)

c. Signal ground

d. Four voltage monitor point

The total housekeeping data will be 10 bps.

5.16.8 Development Status

5.16.8.1 Forerunner instruments.- The instrument will be identical, except for possible improvements, to that on Atmosphere Explorer C.

5.16.8.2 Problems.- No design and manufacturing problems are anticipated. The primary operational problems will be those of minimizing the effects of electric fields, magnetic fields, and gaseous, particle, and electronic contamination of the Orbiter and eliminating photoelectrons from sunlight and parts of the vehicle in the field of view. These operational problems refer to the validity of the data and not to damage of the instrument, except for contamination which can reduce the quantum efficiency of the electron multiplier.

5.17 LANGMUIR PROBE - INSTRUMENT 527

5.17.1 Objective

The Langmuir Probe will measure the electron concentration, ambient (thermal) electron temperature, and plasma potential.

Electron concentration and electron temperature will be important state variables for the local plasma environment. The plasma potential will be the potential of the local plasma measured relative to the potential of the Orbiter and will be an important parameter in interpreting the results of several instruments.

These quantities will be measured by sweeping a probe, which will be extended into the plasma, from a negative to a positive potential measured relative to the plasma potential. The current collected by the

probe may be plotted against the corresponding potential to form a characteristic curve which may then be analyzed to yield the desired quantities. The curve will consist of two saturated regions joined by an exponentially varying region. The electron temperature will be inferred from the exponential portion of the curve and the electron concentration inferred from one of the "saturated" regions. The plasma potential will be inferred from the potential at which the exponential region "joins" one of the "saturated" regions.

This method will differ from the other charged particle detectors in the capability of performing measurements of very low energy (thermal) particles and in performing broadband measurements.

5.17.2 General Description

5.17.2.1 Location.- More than one probe will be required, and the number, which is to be determined, will be dependent upon the experiment. They will be located on the Orbiter (more than one) and on the subsatellites. Several will be required, because the electron concentration can vary significantly over short distances.

The locations of the probes will depend upon the objective of the particular experiment. If the objective is to measure the potential of the ambient plasma, the probes will be located in the front part of the vehicle, because the Orbiter will perturb the plasma. If the objective is to study wakes, most of the probes will be located in the rear.

5.17.2.2 Configuration.- The probe must always be on a boom, even in the case of a subsatellite, to be outside the ion sheath of the vehicle. An estimated boom length for the Orbiter will be at least 50 m and for a dedicated subsatellite 5 to 10 m.

The conducting area of the Orbiter must be at least 1000 times the area of the probe to provide a good "ground", i.e., large enough to receive the probe current without affecting its potential. More specifically, it must be large enough to pass the received charges into the plasma as fast as they are received, so there is no buildup of charge. In the case of the Orbiter, this will be easily fulfilled.

If the probe is cylindrical, it cannot be parallel to the velocity vector of the vehicle, but should be at least 45° to it.

The dimensions and shape will be determined, but a classic design is assumed here. This probe will be a cylindrical conductor 20-cm long and less than 1-cm diameter. A guard conductor of the same diameter, separated by insulation, but on the same axis, will be closer to the

vehicle. The boom, guard, and probe will be along one line. The lead from the probe will run through the middle of the guard. The same voltage which is applied to the probe will also be applied to the guard, but the current need not be measured. The guard will eliminate end effects. The current will be measured with an electrometer.

The following measurements or information will be necessary to interpret the data: magnetic field vector, the Orbiter velocity, sun angle, and information from other electrostatic instruments such as a retarding potential analyzer, low and medium energy electron detectors, and other Langmuir probes.

5.17.2.3 Specifications.- The specifications applicable to this instrument are discussed in the following subparagraphs.

5.17.2.3.1 Range: The applied voltage will be approximately -5 to +20 V. The range of electron temperatures encountered at the expected Orbiter altitude will be 800 K or 1000 K to 3000 K or 4000 K, and this range will be more than covered by the range of the sweep voltage applied.

5.17.2.3.2 Resolution: The electrical parameters will be determined; the spatial resolution, which will be determined by the sampling rate if it is not too high, will be approximately 100 m.

5.17.2.3.3 Sensitivity: The sensitivity of this instrument is yet to be determined.

5.17.2.3.4 Area: The area will be 20 to 75 sq cm.

5.17.2.3.5 Data collection rate: This rate will be typically 10 to 100 samples per second, probably programmable.

5.17.2.3.6 Power: The power will be 5 W average per probe, with a theoretical maximum for a large probe of 20 W.

5.17.2.3.7 Physical dimensions: Estimated dimensions are presented in preceding paragraph 5.17.2.2. Exact dimensions and weight will be confirmed during the design and development phase.

5.17.2.3.8 Contamination protection: An extra circuit will exist to heat the probe to drive off contamination.

5.17.3 Operation

5.17.3.1 Pointing requirements.- The Orbiter pointing accuracy must be within 10°.

5.17.3.2 Stabilization and tracking requirements.- Knowledge of the Orbiter attitude will be required to 1°, and the maximum roll rate of a subsatellite will be 30 rpm.

5.17.3.3 Timeline.- The instrument will be activated, and it will require a short time to warm up the measuring electronics. The mode will be selected. The number of modes is still to be determined, but it may have up to 4 or 5. For example, it may scan throughout the range, or it may sit at one potential and measure the spatial variation. Other modes may involve using only a small part of the dynamic range and obtain finer steps or faster repetition. The voltage scan will be a step scan.

At times, an electrical check or heating of the probe will be performed.

5.17.3.4 Constraints.- The probe will be affected by magnetic and electric field perturbations.

5.17.4 Checkout and Test

5.17.4.1 Boresighting requirements.- A boresight check sufficient to determine the orientation of the probe to 1° will be required.

5.17.4.2 Prelaunch checkout.- The electronics will be checked, but the methods are yet to be determined.

5.17.4.3 Preflight calibration.- No calibration is expected to be feasible.

5.17.4.4 Inflight calibration.- The electronics will be checked by substituting a resistor for the probe and obtaining test data. A calibration may be performed by comparison with an instrument located on a rocket sent from the ground.

5.17.5 Controls

The following controls will be required:

a. Power on/off

b. Sensitivity range control, 3-bit words

c. Mode control word, 8-bit words

d. Heater on/off

5.17.6 Displays

Real-time displays of electron temperature, electron density, and space potential will exist. These will be calculated with the minicomputer from the raw data. The nature of the displays is yet to be determined, but probably numerical displays will be adequate: three digits for the electron temperature, six digits for the electron density, and three digits for the potential.

5.17.7 Data

5.17.7.1 Scientific.- The data will be in a digital form and at a rate yet to de determined. The maximum data rate is estimated at 10 scans/sec, 100 samples/scan, and 8-bits per sample or 8 kbps/sec/probe.

5.17.7.2 Housekeeping.- The number of analog channels at 0 to 5 V is yet to be determined. These will include temperature and voltage measurements. The sample rate will be estimated at once every 8 seconds. In addition, the command status is recorded digitally once every 8 seconds.

5.17.8 Development status

5.17.8.1 Forerunner instruments.- Similar instruments have been flown before, for example, on the Atmosphere Explorer satellites.

5.17.8.2 Problems.- No design and manufacturing problems have been anticipated, but operationally, the measurements will be affected by electrical and magnetic interference.

5.18 ENERGETIC ION MASS ANALYZER - INSTRUMENT 529

5.18.1 Objective

The Energetic Ion Mass Analyzer will be used to measure the energy, mass, and pitch-angle distributions of positive ions in the energy range from 25 keV/nucleon to 10 MeV/nucleon. Its large geometric factor will enable it to serve as a monitor of injected tracers as well as a monitor of the ambient ion environment.

5.18.2 General Description

5.18.2.1 Location.- This instrument will be located on the pallet.

5.18.2.2 Configuration.- The analyzer will basically be a stack of particle detector elements in a telescope configuration; the front element will be very thin and separated from the rear elements by 20 to 25 cm. The front element will be chosen during preliminary design from such candidates as a thin gas proportional counter, thin film scintillator, and thin secondary emission foils. The rear elements will include solid-state detectors and possibly a thin gas proportional counter, depending on the choice of the front element. In operation, the time-of-flight (TOF) of the subject particle will be measured between the first and second elements, and residual energy (E) will be measured in the rear detector. The specific energy loss (dE/dx) will be measured in either the first or second element, depending on whether the first element finally chosen has a good energy response. Proper handling of the TOF, dE/dx, and E will allow a unique determination of the energy and mass of the particle in a redundant way which will be quite immune to accidental events. The telescope will be surrounded, except at the entrance aperture, by an anticoincidence scintillator to preclude accidental events caused by particles entering the side and back.

5.18.2.3 Specifications.- The specifications for this instrument are delineated in the following subparagraphs.

5.18.2.3.1 Energy range: The energy range will be from 25 keV/nucleon to approximately 10 MeV/nucleon.

5.18.2.3.2 Charge range (Z): The charge range will be greater than or equal to 2.

5.18.2.3.3 Mass range: The mass range will be from 4 amu to approximately 56 amu.

5.18.2.3.4 Energy resolution: The energy resolution of the instrument is yet to be determined.

5.18.2.3.5 Mass resolution: The mass resolution will be 1 amu above 12 amu.

5.18.2.3.6 Count rate capability: The count rate capability will be a maximum of 10^6 counts/second.

5.18.2.3.7 Field of view: The field of view will be 60°.

5.18.2.3.8 Geometric factor: The geometric factor is approximately 10 cm^2 sr.

5.18.2.3.9 Physical dimensions: The physical dimensions of size and weight are as follows:

a. Detector assembly - 0.3 x 0.3 x 0.3 m, 0.027 cu m, and 11 kg.

b. Electronics - 0.2 x 0.2 x 0.2 m, 0.008 cu m, and 3 kg.

5.18.2.3.10 Power: The power requirements are 0 W (standby), 28 Vdc regulated, 12.5 W average and maximum (operating), 110 Vac, 400 Hz, and 12.5 VA average and maximum (operating).

5.18.3 Operation

5.18.3.1 Pointing requirements.- The pointing accuracy should be within 2° in pitch, roll, and yaw.

5.18.3.2 Stabilization.- The allowable Orbiter rate should be less than 20 deg/sec.

5.18.3.3 Orbiter attitude knowledge.- The attitude of the Orbiter should be known to within 2°.

5.18.3.4 Orbital parameters.- The orbital parameters will be defined by experiment objectives.

5.18.3.5 Timeline of data takes.- Instrument operation will be continuous.

5.18.3.6 Constraints.- An operating temperature range of -20° to 0° C is desired. The instrument should be turned off above 40° C, and instrument temperature should not exceed 50° C in any case.

5.18.3.7 Contamination.- Depending upon the sensor type selected and the overall prelaunch contamination levels, the instrument design may incorporate a self-contained gas purge for prelaunch.

5.18.3.8 Acoustic.- Depending upon sensor selection and anticipated acoustic levels, the instrument may require an entrance aperture cover which will be removed (remotely) after orbital insertion.

5.18.4 Checkout and Test

5.18.4.1 Boresighting requirements.- These will be only as required to achieve the 2° pointing accuracy.

5.18.4.2 Prelaunch checkout.- Low voltage power will be applied, and the various housekeeping measurements will be monitored. An internal pulser sequence will be activated to check gains, discriminator levels, and counting circuits. High voltage will be applied to those detectors which can operate at atmospheric pressure and their housekeeping parameters will be measured.

5.18.4.3 Preflight calibration.- Possibly a built-in weak radioactive source will be commanded into the field of view of the sensors. In addition, other weak radioactive sources (not a part of the instrument) might be used.

5.18.4.4 Inflight calibration.- An automatic calibration sequence, which will drive pulser ramps every 10 minutes to check discriminators, will be incorporated. Possibly a mechanically driven weak radioactive source will be incorporated to check detector calibration.

5.18.5 Controls

Controls for instrument on/off, individual detector on/off calibration, and contingency modes of operation will be required. The total number of detectors and all contingencies are yet to be determined. However, all commands should be adequately covered by two 8-bit command words.

5.18.6 Displays

All housekeeping parameters should be displayable on a CRT upon command. The discrete channel digital data, decommutated and accumulated, should be displayable on a CRT.

5.18.7 Data

5.18.7.1 Scientific.- Scientific data will be: a serial digital bit stream of three-parameter fully analyzed events composed of 8-bit words at 6 kbps; and, a serial digital bit stream of discrete channel data composed of 8-bit words at 500 bps.

5.18.7.2 Housekeeping.- There will be approximately five channels of electronics box data, 0 to 5 V level, to be digitized by the remote acquisition unit (RAU) on the pallet into 8-bit words and sampled at approximately 0.5 word/sec for a total of 4 bps. In addition, there will be 10 channels of detector housekeeping data to be digitized by the RAU on the pallet into 8-bit words and sampled at approximately 1 word/sec for a total of 8 bps.

5.18.8 Development Status

5.18.8.1 Forerunner instruments.- Instruments utilizing sensor systems and techniques similar to the ones in this instrument are presently operating as laboratory devices. Although the lower energy limit and the timing accuracy of this instrument are stringent, both are within the state-of-the-art.

5.18.8.2 Problems.- The design and manufacturing problems center around the design of a suitable, thin, front sensor for the telescope and the achievement of adequate time-of-flight resolution. Considerable laboratory testing (calibration and adjustment) will be required. The operational problems are yet to be evaluated or determined.

Operational: (TBD).

5.19 HIGH-FREQUENCY QUADRUPOLE PROBE - INSTRUMENT 530

5.19.1 Objective

This instrument will determine electron density and temperature with high precision and at high measurement rates and will determine the electron distribution function when the plasma is not in equilibrium. The purpose of this instrument is to provide basic electron density and temperature data for other experiments.

5.19.2 General Description

5.19.2.1 Location.- This instrument's sensors will be mounted on the boom, and the electronics will be mounted on a pallet or a subsatellite.

5.19.2.2 Configuration.- The High-Frequency Quadrupole Probe will consist of a sensor array coupled to a transmitter/receiver unit. This in turn will transmit data to high-frequency transfer function instrumentation and a correlator capable of auto- and/or cross-correlation.

The sensor array will consist of two small antennas approximately 10 cm in length separated by 1 m. Two pairs will be used to cancel the possible effect of long-wave EMI. These antennas will be fixed. A third pair, which will have variable separation and variable angular orientation with respect to the first pair, will be desirable. The array will weigh about 3 kg and is to be mounted at the end of a 20- to 50-m boom. An illustration of the antenna array configuration is presented in figure 5-15.

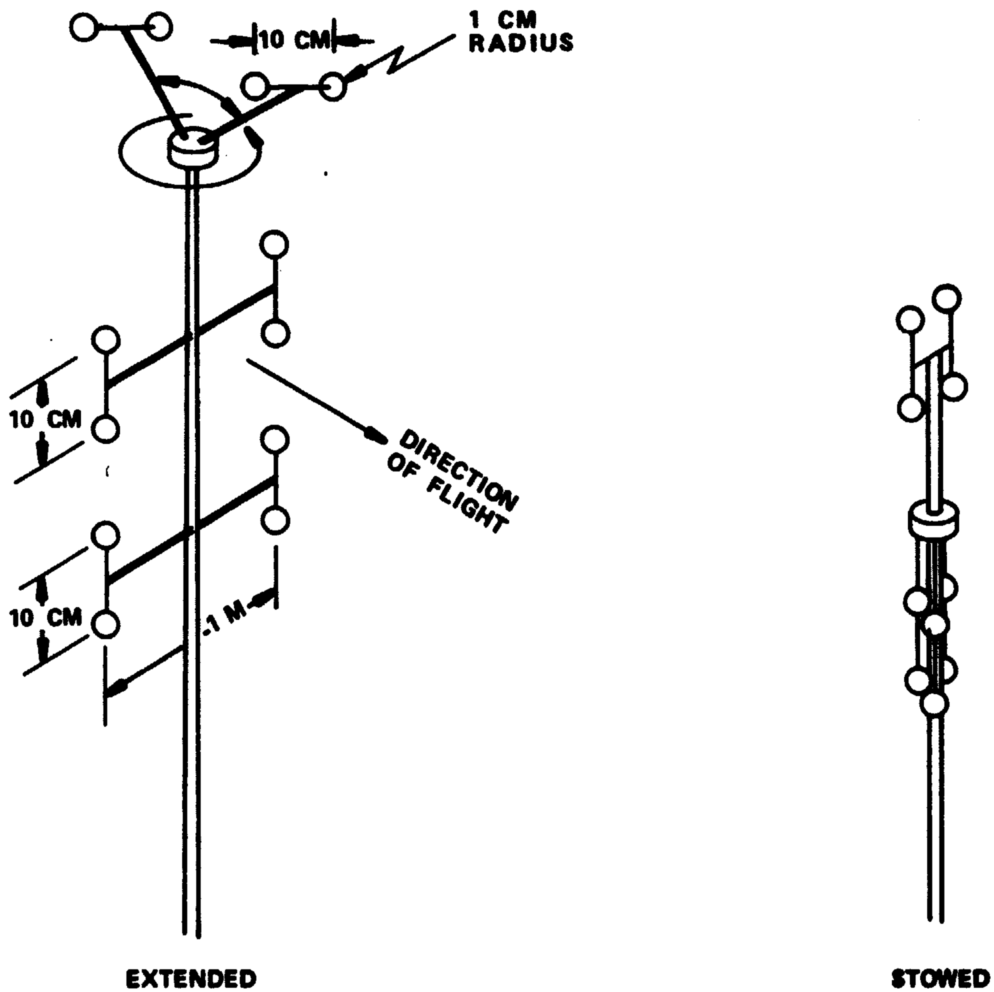

Figure 5-15.- Antenna configuration.

A programmable transfer function meter will include the transmitter/receiver electronics. In the active mode, a swept frequency, low amplitude (1-V) signal will be applied to the transmitting antenna. The receiver, having narrow bandwidth, will be continuously tuned to the variable frequency of the transmitter. The frequency transmitted will be 0.1 MHz to 20 MHz. By adding or subtracting the excitation damping frequency with the plasma resonant frequency, beat frequencies will be derived. The antiresonant points will be used in the mathematics required to calculate electron density and temperature. The preceding explanation is over simplified; for a more detailed explanation see "High Frequency Quadrupole," Journal of Plasma Physics, Chasseriaux, Debrie, and Renard, vol. 8, part 2, pp. 231-253.

In the instrument's passive mode, antennas in a pair will be connected independently to a pair of receivers, and the cross-correlation function of the two outputs will be computed. From this, the cross-spectrum will be computed, and if the received signals are due to the natural plasma microfield, the electron distribution function can be interpreted from the cross-spectrum. In this mode, a wideband (20 MHz) cross-correlator will be used.

Data from a sensitive magnetometer operating at the same time may be desirable during final data reduction.

5.19.2.3 Specifications.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.19.2.3.1 Frequency: The frequency will be from 0.1 to 20 MHz swept.

5.19.2.3.2 Resolution: Earlier instruments of this type used receivers having a fixed gain of about 104 dB. During the design and development, the exact resolution will be confirmed.

5.19.2.3.3 Sensitivity: Sensitivity in the range of 0.5 μV has been used in the past. During the design and development, the exact sensitivity will be confirmed.

5.19.2.3.4 Data collection rate: The instrument will have a different data rate for the active and passive modes. These rates are:

a. Active mode: 2024 sps per parameter

b. Passive mode: 128 sps per parameter

5.19.2.3.5 Power: The power requirements are as follows:

a. Antenna deployment: 52 W

b. Transfer function meter: 48 W

c. Correlator: 200 W

d. Total: 300 W

5.19.2.3.6 Physical dimensions: The physical dimensions are as follows:

a. Sensor array (antenna) - 0.1 cu m stored, 1.5 cu m deployed, and 3 kg in weight

b. Transfer function meter - 0.5 x 0.5 x 0.2 m, and 50 kg in weight

c. Correlator - 0.5 x 0.5 x 0.8 m, and 200 kg in weight.

5.19.2.3.7 Other: Because of EMI requirements, this unit should be placed on a 20- to 50-m boom.

5.19.3 Operation

5.19.3.1 Pointing requirements.- Orbiter pointing accuracy will be 5° in each angle. Sensor attitude should be known to 1°. The allowable Orbiter rate will be less than 1 deg/sec.

5.19.3.2 Timeline.- The instrument will be operated 10 minutes to 3 hours maximum. Typical standby time will be 1 hour.

5.19.3.3 Constraints.- Orbiter orientation should be such that it will not be creating a wake in the plasma field upstream of the antennas.

5.19.4 Checkout and Test

The checkout and test requirements are to be determined.

5.19.5 Controls

The following controls can be manual or under computer control:

a. Power up (on/off)

b. Movable antenna positioning

   1. Angular

   2. Separation

c. Choice of antenna set (three available)

d. Active or passive mode

The operating frequency in the active mode will be under computer control.

5.19.6 Displays

The following displays should be available on a digital CRT.

a. Active-mode display of transfer function (amplitude and phase or real and imaginary parts versus frequency).

b. Passive-mode display of auto- or cross-spectrum calculated from correlation functions either internal to this instrument or by the Orbiter computer.

5.19.7 Data

All data will be in a digital format.

Parameter	Word length, bits	Sampling rate, sps
Transmitted RF current	12	2024
Transmitted RF frequency	16	2024
Received RF amplitude	16	2024
Recorded RF phase	12	2024
Autocorrelation, channel 1	8	128

Parameter	Word length, bits	Sampling rate, sps
Autocorrelation, channel 2	8	128
Cross-correlation, channel 1 delayed	8	128
Cross-correlation, channel 2 delayed	8	128
Housekeeping		
(Movable antenna orientation)		
Opening angle (separation)	12	8
Azimuth angle (direction)	12	8

5.19.8 Development Status

5.19.8.1 Forerunner instruments.- CISASPE rocket experiment launched in December 1971. This instrument operated in the active mode only and used rough approximations of the earth's magnetic field.

5.19.8.2 Problems.- The following subparagraphs discuss some of the anticipated problems with this instrument.

5.19.8.2.1 Design and manufacturing: The design and manufacture of this instrument should be within the state-of-the-art. It is believed that the weight and size of the correlator will be quite large. With good design and packaging techniques, this unit can probably be reduced in size and weight to the same dimensions as the transfer function meter.

5.19.8.2.2 Operational: This experiment will be highly susceptible to magnetic and electromagnetic interference. At the sensors, the magnetic perturbation should be less than one-tenth of the earth's field, which at this altitude is estimated to be between 0.2 and 0.5 gauss.

5.20 ENERGETIC ION MASS ANALYZER FOR AMPS SUBSATELLITE - INSTRUMENT 531

5.20.1 Objectives

The Energetic Ion Mass Analyzer will be used to measure the energy, mass, and pitch angle distributions of positive ions in the energy range

from 25 keV/nucleon to 10 MeV/nucleon. It can also serve as a monitor of injected tracers as well as a monitor of the ambient ion environment.

5.20.2 General Description

5.20.2.1 Location.- This instrument will be located on the subsatellite.

5.20.2.2 Configuration.- The analyzer will basically be a stack of particle detector elements in a telescope configuration; the front element will be very thin and separated from the rear elements by 10 to 15 cm. The front element will be chosen during preliminary design from such candidates as a thin gas proportional counter, thin film scintillator, and thin secondary emission foils. The rear elements will include solid-state detectors and possibly a thin gas proportional counter, depending on the choice of the front element. In operation, the TOF (time-of-flight) of the subject particle will be measured between the first and second elements, and residual E (energy) will be measured in the rear detector. The dE/dx (specific energy loss) will be measured in the first or second element, depending on whether the first element finally chosen has a good energy response. Proper handling of the TOF, dE/dx, and E will allow a unique determination of the energy and mass of the particle in a redundant way which will be quite immune to accidental events.

5.20.2.3 Specifications.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.20.2.3.1 Energy range: The energy range will be from 25 keV/nucleon to approximately 10 MeV/nucleon.

5.20.2.3.2 Charge range (Z): The charge range will be greater than or equal to 2.

5.20.2.3.3 Mass range: The mass range will be from 4 amu to approximately 56 amu.

5.20.2.3.4 Energy resolution: The energy resolution is yet to be determined.

5.20.2.3.5 Mass resolution: The mass resolution will be 1 amu above 12 amu.

5.20.2.3.6 Count rate capability: The count rate capability will be 10^6 counts/second.

5.20.2.3.7 Field of view: The field of view will be 60°.

5.20.2.3.8 Geometric factor: The geometric factor will be approximately 0.1 to 1 cm^2 sr.

5.20.2.3.9 Physical dimensions: The physical dimensions will be:

a. Detector assembly - 0.15 x 0.12 x 0.2 m, 0.0036 cu m, and 3.5 kg in weight.

b. Electronics - 0.17 x 0.17 x 0.18 m, 0.0052 cu m, and 2.5 kg in weight.

5.20.2.3.10 Power: The power required is 28 Vdc with OW in standby and 12 W average and maximum while operating.

5.20.3 Operation

5.20.3.1 Pointing requirements.- The pointing accuracy should be within 2° in the pitch, roll, and yaw axes.

5.20.3.2 Stabilization.- The allowable subsatellite rate should be less than 20 deg/sec.

5.20.3.3 Subsatellite attitude knowledge.- The attitude of the subsatellite should be known to within 2°.

5.20.3.4 Orbital parameters.- The Orbital parameters will be defined by experiment objectives.

5.20.3.5 Timeline of data takes.- Instrument operation will be continuous.

5.20.3.6 Constraints.- An operating temperature range of -20° to 0° C is desired. The instrument should be turned off above 40° C, and instrument temperature should not exceed 50° C in any case.

5.20.3.7 Acoustic.- Depending upon sensor selection and the anticipated acoustic levels, the instrument may require an entrance aperture cover which will be removed (remotely) after orbital insertion.

5.20.3.8 Contamination.- Depending upon the sensor types finally chosen, the instrument may be sensitive to contaminants.

5.20.4 Checkout and Test

5.20.4.1 Boresighting requirements.- These will be only as required to achieve the 2° pointing accuracy.

5.20.4.2 Prelaunch checkout.- Low-voltage power will be applied and the various housekeeping measurements monitored. An internal pulser sequence will be activated to check gains, discriminator levels, and counting circuits. High voltage will be applied to those detectors which can operate at atmospheric pressure, and their housekeeping parameters will be measured.

5.20.4.3 Preflight calibration.- Possibly a built-in weak radioactive source will be commanded into the field of view of the sensors. In addition, other weak radioactive sources (not a part of the instrument) might be used.

5.20.4.4 Inflight calibration.- An automatic calibration sequence will be incorporated which will drive pulser ramps every 10 minutes to check discriminators. Possibly a mechanically driven weak radioactive source will be incorporated to check detector calibration.

5.20.5 Controls

Controls for instrument on/off, individual detectors on/off, calibration, and contingency modes of operation will be required. The total number of detectors and all contingencies are yet to be determined. However, all commands should be adequately covered by two 8-bit command words.

5.20.6 Displays

All housekeeping parameters should be displayable on a CRT upon command. The discrete channel digital data, decommutated and accumulated, should also be a displayable on a CRT.

5.20.7 Data

5.20.7.1 Scientific.- Scientific data will be a serial digital bit-stream of three-parameter fully analyzed events composed of 8-bit words at 450 bps and a serial digital bit-stream of discrete channel data composed of 8-bit words at 349 bps.

5.20.7.2 Housekeeping.- Housekeeping data will be internally subcommutated, digitized, and presented at 1 bps.

5.20.8 Development Status

5.20.8.1 Forerunner instruments.- Instruments utilizing the sensor system and techniques similar to the ones in this instrument are presently operating as laboratory devices. Although the lower energy limit and the timing accuracy of this instrument are stringent, both are within the state-of-the-art.

5.20.8.2 Problems.- The main design and manufacturing problem will be the design of a suitable, thin, front sensor for the telescope and the achievement of adequate time-of-flight resolution. Considerable laboratory testing (calibration and adjustment) will be required. Operational problems have yet to be determined.

5.21 DC ELECTRIC FIELD - INSTRUMENT 535

5.21.1 Objective

This instrument will measure the dc electric field vector and its time and space variations and gradients. The field variations and gradients will be a result of natural magnetospheric and ionospheric winds and artificial perturbations of the plasma medium by active experiments.

5.21.2 General Description

5.21.2.1 Location.- This instrument will be mounted on the subsatellite.

5.21.2.2 Configuration.- A subsatellite will be required that can contain furlable boom (antenna) mechanisms, electronics, power supply, inertial stabilization, and telemetry. In addition, the Vector Magnetometer (Instrument 548) should be contained in this subsatellite as these data will be required to eliminate the effect of the earth's magnetic field from the electric field data. The two instruments can share the telemetry link. The symmetric double probe floating potential technique can be used.

Three pairs of antennas will be required and mounted orthogonally on the +X, -X, +Y, -Y, +Z, and -Z axes. The antenna probes can be deployed, retracted, or changed in length individually. Each probe will have a maximum length of 20 meters. There will be a minimum length of separation when deployed, based on the dimensions and electrical characteristics of the subsatellite.

In addition to the electronics required for the basic field measurements, a variety of logic circuits will be used for special functions such as antenna deployment, magnetic-field vector subtractions, and presentation of data.

5.21.2.3 Specifications.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.21.2.3.1 Sensitivity: Electric fields in the ionosphere perpendicular to the magnetic field range from less than 1 mV/m up to 100 mV/m. Fields parallel to the magnetic field are expected to be less than 10 mV/m. Therefore, 20-meter opposed probes could yield a potential as high as 4 V and as low as perhaps a few millivolts.

5.21.2.3.2 Data collection rate: Approximately 20 measurements of the electric field vector per second will be required. This will require 2.0 kb of data, if housekeeping is included.

5.21.2.3.3 Power: The power required by this instrument is as follows:

a. Antenna deployment: 36 W, 28 V

b. Data collection: 6 W, 28 V

c. Standby: 2 W, 28 V

5.21.2.3.4 Physical dimensions: The physical dimensions of this instrument are as follows:

a. Antenna probes (stored) - 0.03 cu m and 30 kg in weight.

b. Electronics - 0.006 cu m and 5 kg in weight.

c. Subsatellite (including instrument) - approximately 1 m diam x 1 m long and 70 kg in weight.

5.21.2.3.5 Other: A three-axis stabilized subsatellite is preferred. Some temperature control will be required to protect the electronics and power supply. Also a thermal scheme will be required to keep the probes

from flexing due to the gradient from one side to the other. Perforated booms have been used successfully in the past to solve this type of problem.

5.21.3 Operation

5.21.3.1 Pointing requirements.- Pointing requirements are not applicable to this instrument.

5.21.3.2 Stabilization.- Although inertial stabilization is not a firm requirement, it is preferred over spin stabilization. The Vector Magnetometer (Instrument 548) will require a stable platform. Spin stabilization will introduce the requirement for more complex data reduction programs and more computer time to remove the effect of the spin. An inertially stabilized platform for the instrument will be more economical if very much data are processed.

5.21.3.3 Tracking requirements.- The location of the satellite in the earth's inertial coordinates must be known within an error radius of approximately 50 m.

5.21.3.4 Timeline.- Operation will be essentially continuous after deployment. Because of Orbiter priorities, the subsatellite may have to contain its own recorder, which will play back on command.

5.21.3.5 Constraints.- Inertial orientation known to 0.1° will be required. Inertial alignment with the earth's magnetic field will be assumed, and because of the rapidly changing vector direction, particularly in polar orbits, some relaxation may be needed for this experiment.

5.21.4 Checkout and Test

The checkout and test requirements have yet to be determined.

5.21.5 Controls

Controls will be required for the following:

a. Power up (or this can be accomplished prior to subsatellite deployment)

b. Antenna deployment (six single or three pairs)

5.21.6 Displays

For real-time data readout, display of data should be accompanied by a computer subtraction and simultaneous display of the subsatellite velocity vector in the earth's magnetic field. This could possibly be done by a minicomputer aboard the subsatellite. Subsatellite location in relation to the earth's inertial coordinates might also be displayed. Antenna probe positions should be available.

5.21.7 Data

5.21.7.1 Scientific.- The scientific data will consist of approximately 20 measurements of the dc electric field vector per second. These data will be combined with the housekeeping data to form a bit stream of 2 kb of 8-bit words.

5.21.7.2 Housekeeping.- Housekeeping data will include subsatellite performance and antenna status. Other data may include the Vector Magnetometer (Instrument 548) data, a computer subtraction of these data from the electric field data, and subsatellite location in earth's inertial coordinates.

All data can be displayed numerically (if required) either on digital readout or printout. Displays will include:

a. Three E-field vectors and a combined field vector.

b. V_s (satellite velocity vector) x B (vector of earth's magnetic field).

c. Display of V x B subtracted from total field to give E.

The above will require six numerical displays or printouts. The display will have to be integrated over time, since data will be collected at 20 sps.

5.21.8 Development Status

5.21.8.1 Forerunner instruments.- Similar instruments have been installed on the following satellites - OGO-5, OGO-6, Injun 5, Imp-I, and Imp-J. Other dc electric field instruments will be flown on the new satellites ISEE-A, GEOS, and SCATHA.

5.21.8.2 Problems.- No design and manufacturing problems are anticipated; however, operationally, very low EMI will be needed so that E-field measurements will not be covered by other noise. Possibly, other electronics could be high frequency, which can be filtered out of the dc field data. Thermal problems have been discussed previously in this description.

5.22 ION MASS AND DISTRIBUTION ANALYZER - INSTRUMENT 537

5.22.1 Objective

This instrument will be used to measure the densities, temperatures, and drift velocities of thermal ions in the mass range of 1 to 64 amu and in the energy range of 0.1 to 20 eV. The instrument will serve to monitor the natural environment as well as for ions injected as tracers.

5.22.2 General Description

5.22.2.1 Location.- This instrument will be located on the boom.

5.22.2.2 Configuration.- The instrument will combine energy and mass analysis. A retarding potential analyzer (RPA) will serve to analyze in an integral mode the incoming ions in energy. The RPA will consist of a number of transmission grids of which the heart will be a retarding grid whose voltage can be varied. In the present instrument configuration, the retarding grid voltage will be scanned from -5 to + 30 V.

Following the RPA will be the mass analyzer composed of an accelerating grid, magnetic field, and particle detectors (channeltrons or electron multipliers). Three particle detectors will be incorporated in each analyzer to measure three mass species simultaneously (e.g., H^+, He^+, O^+), so that temporal resolution will be increased. In a typical operating sequence, the accelerating grid will be set to a predetermined voltage, which will define the three mass species, and the RPA retarding grid voltage will be varied to scan the desired energy range. The accelerating grid voltage will then be stepped to another predetermined value for a different set of mass species, and the RPA retarding potential will again be scanned. This process will be repeated until the desired mass range is covered.

The instrument will operate in four commandable modes:

a. Survey mode - This mode will be a scan over the complete mass and energy range with a complete cycle occurring approximately in 1 second.

b. Fast temperature and drift mode - In this mode, the mass selector will be set to accept three mass species, and a scan will be made over the complete energy range. The cycle time will be approximately 0.1 second.

c. Density mode - The RPA will be set to accept all energies, and a scan over the complete mass range will be performed. The cycle time will be approximately 0.02 second.

d. Fast density mode - The RPA will be set to accept all energies and the mass analyzer set to pass three preselected mass species. The cycle time will be 0.001 second which will be the basic cycle time of the instrument.

Three of the described sensor heads will be mounted in three orthogonal directions on a pointing platform on a 30-meter boom. The potential of the sensor end of the boom must be variable to keep the potential of the sensor heads at or near the same potential as the ambient plasma.

5.22.2.3 Specifications.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.22.2.3.1 Energy range: The energy range measured will be from 0.1 to 20 eV.

5.22.2.3.2 Energy resolution: The energy resolution will be in 0.1 eV steps from 0.1 to 5 eV. The interval between 5 and 20 eV will be divided into equilogarithmically spaced steps. The total number of energy steps for the entire energy range will be 64.

5.22.2.3.3 Mass range: The instrument will measure masses in the range 1 to 64 amu.

5.22.2.3.4 Mass resolution: The mass resolution ($\Delta M/M$) will be one twenty-fifth.

5.22.2.3.5 Count rate capability: The particle sensors will be capable of counting up to 10^7 counts/seconds.

5.22.2.3.6 Field of view: The opening full angle of the instrument will be adjustable by external collimation, set before launch, from 5° to 180°.

5.22.2.3.7 Power: The power requirements to the instrument will be as follows:

Sensors:

a. Voltage - 28 ± 4 Vdc

b. Standby power - 3 W

c. Average power - 5 W

d. Maximum power - 8 W (occurs during calibration cycles)

Electronics:

a. Voltage - 28 ± 4 Vdc

b. Standby power - 2 W

c. Average power - 10 W

d. Maximum power - 10 W

5.22.2.3.8 Physical dimensions: The physical dimensions of this instrument are as follows:

a. Sensor head (3) - 0.2 x 0.2 x 0.1 m (aperture on 0.1 x 0.2 m face), 0.12 cu m (stored and operational) and 2.0 kg in weight each for a total of 6.0 kg.

b. Electronics box - 0.02 cu m and 9 kg in weight.

5.22.3 Operation

5.22.3.1 Pointing requirements.- The instrument pointing accuracy will be, at worst, 1°.

5.22.3.2 Stabilization.- The stabilization function is not applicable to this instrument.

5.22.3.3 Orbiter attitude knowledge.- The attitude of the Orbiter will be known to within 1°.

5.22.3.4 Timeline of data takes.- The instrument will operate 50 to 90 percent of the time and will be in standby status 50 to 10 percent of the time.

5.22.3.5 Constraints.- Instrument temperature should be restricted to the interval -10° to +50° C.

5.22.4 Checkout and Test

5.22.4.1 Boresighting requirements.- The instrument sensors will be aligned with respect to the pointing platform so as to achieve a pointing accuracy of 1°.

5.22.4.2 Prelaunch checkout.- Prelaunch checkout will consist of exercising the individual low-voltage subsystems (e.g., energy selector and analog and digital electronics) and observing housekeeping parameters. In addition, pulses will be fed into the sensor amplifier inputs to exercise the counting system. The high voltage portions of the instrument cannot be exercised at atmospheric pressure.

5.22.4.3 Preflight calibration.- No preflight calibration is necessary.

5.22.4.4 Inflight calibration.- A filament particle source, such as a lithium source, will be incorporated immediately in front of each sensor (channeltron or electron multiplier) and turned on periodically during flight to check the integrity of each sensor. The calibration sequence will be performed approximately every 12 hours and will occupy a few minutes.

5.22.5 Controls

The following commands will be necessary to control the instrument.

a. Low-voltage power - on/off

b. High-voltage power - on/off

c. Operation mode select - 6-bit word

d. Analyzer bias potentials select - 12-bit word

5.22.6 Displays

Ten analog traces (CRT) of the digital (converted to analog) data (response of 200 Hz) will be required. Included in these will be count rates from each sensor and the stepped voltage of the RPA.

The analog housekeeping parameters (converted to digital) will be displayed upon command.

5.22.7 Data

The sensor heads will output both digital and analog data converted to digital), and the electronics box will output analog data (converted to digital) with the following characteristics:

a. Digital

1. Head 1 - three sensors, 10^3 8-bit words/sec/sensor, total 24 kbps

2. Head 2 - three sensors, 10^3 8-bit words/sec/sensor, total 24 kbps

3. Head 3 - three sensors, 10^3 8-bit words/sec/sensor, total 24 kbps

b. Analog

1. Sensors - 10 parameters, 0 to 5 V, converted to 8-bit digital words at 10 sps, total 80 kbps

2. Electronics - 20 parameters, 0 to 5 V, converted to 8-bit digital words at 20 sps, total 160 bps

5.22.8 Development Status

5.22.8.1 Forerunner instruments.- Retarding potential analyzers (RPA) and Ion Mass Spectrometers have been flown before. RPA's were flown on OGO-5, OGO-6, and AE satellites, and Ion Mass Spectrometers have flown on the AE satellites. The present instrument which will be a combination of the two concepts is within the state-of-the-art.

5.22.8.2 Problems.- The design and manufacturing problems have yet to be determined. Two operational problems will be possible.

a. The detecting elements for the sensor heads will be either channeltrons or electron multipliers, both of which will be susceptible to contaminants.

b. Because the sensor heads must be at or near the potential of the plasma being probed, some means of active control of the potential at the end of the boom on which the sensors will be mounted must be implemented. Data from the sensors can be utilized to serve as the active sensing element for this control.

5.23 SUBSATELLITE ION MASS AND DISTRIBUTION ANALYZER - INSTRUMENT 538

5.23.1 Objective

This instrument will be used to measure the densities, temperatures, and drift velocities of thermal ions in the mass range of 1 to 64 amu and in the energy range of 0.1 to 20 eV. The instrument will serve to monitor the natural environment as well as for ions injected as tracers.

5.23.2 General Description

5.23.2.1 Location.- This instrument will be mounted on the subsatellite.

5.23.2.2 Configuration.- The instrument will combine energy and mass analysis. Three sensor heads will be mounted on a subsatellite; one parallel, one antiparallel, and one perpendicular to the spin axis.

A retarding potential analyzer (RPA) will serve to analyze in an integral mode the incoming ions in energy. The RPA will consist of a number of transmission grids the heart of which will be a retarding grid whose voltage will be varied. In the present instrument, the retarding grid voltage will be scanned from -5 to +30 V.

Following the RPA will be the mass analyzer composed of an accelerating grid, magnetic field, and a particle detector (channeltron or electron multiplier). In a typical operating sequence, the accelerating grid will be set to a predetermined voltage, which will define the mass species, and the RPA retarding grid voltage will be varied to scan the desired energy range. The accelerating grid voltage will then be stepped to another predetermined value for a different mass species and the RPA retarding potential will again be scanned. This process will be repeated until the desired mass range is covered.

The instrument will operate in four commandable modes:

a. Survey mode - This mode will be a scan over the mass and energy range with a complete cycle occurring approximately 30 seconds.

b. Fast temperature mode - In this mode, the mass selector will be set to accept one mass species, and a scan will be made over the complete energy range. The cycle time will be approximately 2.0 seconds.

c. Density mode - The RPA will be set to accept all energies, and a scan over the complete mass range will be performed. The cycle time will be approximately 0.5 second.

d. Fast density mode - The RPA will be set to accept all energies and the mass analyzer set to pass one mass species. The cycle time will be 0.01 second, which will be the basic cycle time of the instrument.

e. Density, temperature - The RPA will be scanned over a restricted energy range, and the mass analyzer will be set to accept one mass species. The cycle time will be approximately 0.05 second.

5.23.2.3 Specifications.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.23.2.3.1 Energy range: The energy range measured will be from 0.1 to 20 eV.

5.23.2.3.2 Energy resolution: The energy resolution will be in 0.1 eV steps from 0.1 to 5 eV. The interval between 5 and 20 eV will be divided into equilogarithmically spaced steps. The total number of energy steps for the entire energy range will be 64.

5.23.2.3.3 Mass range: The instrument will measure masses in the range of 1 to 64 amu.

5.23.2.3.4 Mass resolution: The mass resolution ($\Delta M/M$) will be one twenty-fifth.

5.23.2.3.5 Count rate capability: The particle sensors will be capable of counting up to 10^7 counts/second.

5.23.2.3.6 Field of view: The opening full angle of the instrument will be adjustable by external collimation, set before launch, from 10° to 180°.

5.23.2.3.7 Power: The power requirements to the instrument will be as follows:

a. Sensors:

1. Voltage - 28 ± 4 Vdc

2. Standby power - 1 W

3. Average power - 3 W

4. Maximum power - 5 W (occurs during calibration cycle)

b. Electronics:

1. Voltage - 28 ± 4 Vdc

2. Standby power - 2 W

3. Average power - 7 W

4. Maximum power - 7 W

5.23.2.3.8 Physical dimensions: The physical dimensions of the instrument are as follows:

a. Sensor heads (3) - 0.13 x 0.13 x 0.2 m, 0.004 cu m, and 1.0 kg each for a total weight of 3.0 kg.

b. Electronics box - 0.15 cu m and 2 kg in weight.

5.23.3 Operation

5.23.3.1 Pointing requirements.- The instrument pointing accuracy will be, at worst, 1°.

5.23.3.2 Stabilization.- No stabilization specification is applicable to this instrument.

5.23.3.3 Subsatellite attitude knowledge.- The attitude of the subsatellite should be known to within 1°.

5.23.3.4 Timeline of data takes.- The instrument will operate 50 to 90 percent of the time and will be in standby status 50 to 10 percent of the time.

5.23.3.5 Constraints.- Instrument temperature should be restricted to the interval -10° to +50° C.

5.23.4 Checkout and Test

5.23.4.1 Boresighting requirements.- The instrument sensors will be aligned with respect to the subsatellite so as to achieve a pointing accuracy of 1°.

5.23.4.2 Prelaunch checkout.- Prelaunch checkout will consist of exercising the individual low-voltage subsystem (e.g., energy selector and analog and digital electronics) and observing housekeeping parameters. In addition, pulses will be fed into the sensor amplifier inputs to exercise the counting system. The high-voltage portions of the instrument cannot be exercised at atmospheric pressure.

5.23.4.3 Preflight calibration.- No preflight calibration is required.

5.23.4.4 Inflight calibration.- A filament particle source such as a lithium source will be incorporated immediately in front of each sensor (channeltron or electron multiplier) and turned on periodically during flight to check the integrity of each sensor. The calibration sequence will be performed approximately every 12 hours and will occupy a few minutes.

5.23.5 Controls

The following commands will be necessary to control the instrument:

a. Low-voltage power - on/off

b. High-voltage power - on/off

c. Operation mode select - 8-bit word

d. Analyzer bias potentials select - 10-bit word

5.23.6 Displays

Four analog traces (CRT) of the digital (converted to analog) data, with a response of 200 Hz, will be required. Included in these traces will be count rates from each sensor head and the stepped voltage of the RPA.

The analog housekeeping parameters (converted to digital) will be displayed upon command.

5.23.7 Data

The sensor heads will output both digital and analog data, and the electronics box will output analog data. (The analog data will be digitized by subsatellite analog to digital converters.)

a. Digital

1. Head 1 - three sensors, 100 8-bit words/sec/sensor, total 800 bps

2. Head 2 - three sensors, 100 8-bit words/sec/sensor, total 800 bps

3. Head 3 - three sensors, 100 8-bit words/sec/sensor, total 800 bps

b. Analog

1. Sensors - 10 parameters, 0 to 5 V, converted to 8-bit digital words at 10 sps, total 80 bps

2. Electronics - 20 parameters, 0 to 5 V, converted to 8-bit digital words at 20 sps, total 160 bps

5.23.8 Development Status

5.23.8.1 Forerunner instruments.- Retarding potential analyzers (RPA) and Ion Mass Spectrometers have been flown before. RPA's were flown on OGO-5, OGO-6 and AE satellites, and Ion Mass Spectrometers have flown on the AE satellites. The present instrument which is a combination of the two concepts is within the state-of-the-art.

5.23.8.2 Problems.- No design and manufacturing problems are anticipated. However, operationally, the detecting elements for the sensor heads will be either channeltrons or electron multipliers, both of which are susceptible to contaminants and must be protected.

5.24 MEDIUM ENERGY ION MASS ANALYZER - INSTRUMENT 540P

5.24.1 Objective

The Medium Energy Ion Mass Analyzer will measure the energy, mass, and pitch-angle distribution of ions in the range from 10 eV $\leq E/Q \leq$ 50 keV. It will be used to monitor the natural ion environment or the ions injected by the Orbiter as tracers.

5.24.2 General Description

5.24.2.1 Location.- This instrument will be located on the pallet.

5.24.2.2 Configuration.- The instrument will combine energy and mass analysis. Ions entering the instrument will be sorted in energy using an electrostatic analyzer. Following this will be either: (1) a magnetic analyzer composed of a permanent magnet sector with an array of channeltrons along its exit focal plane; or (2) a velocity selector composed of crossed electric and magnetic fields with either a channeltron or electron multiplier array for particle detection. In either case, the energy range will be scanned by varying the voltage across the deflection plates of the electrostatic analyzer. If the mass analysis used is method 1, the radii of curvature defined by the channeltron array, along with the energy information, will determine the masses. If method 2 is used, the crossed electric field will be scanned and the velocity information, along with the energy determination, will determine the mass.

5.24.2.3 Specifications.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.24.2.3.1 Energy range: The energy range will be 10 eV $\leq E/Q \leq$ 50 keV where E is the ion energy and Q is the number of electronic charges on the ion.

5.24.2.3.2 Energy resolution: The energy resolution ($\Delta E/E$) will be 0.1.

5.24.2.3.3 Mass range: The analyzer will be capable of focusing, up to 50 keV, ions for which $M/Q \leq 16$ where M is the ion mass in atomic mass units and Q is the number of electronic charges on the ion.

5.24.2.3.4 Mass resolution: The mass resolution $\Delta(M/Q)/(M/Q)$ will be 1/16.

5.24.2.3.5 Data collection rate: The particle sensor will be capable of a counting rate of up to 10^7 counts/second.

5.24.2.3.6 Field of view: The angular resolution of the instrument will be 10°, and the instrument will be mechanically scanned through an angular range of 90° by an onboard scanning platform.

5.24.2.3.7 Geometric factor: The instrument will have a geometric factor of approximately 1 cm^2 sr.

5.24.2.3.8 Power: The Orbiter power will be routed to the instrument through the electronics box and will be 28 Vdc: Power usage will be 50 W in standby, 50 W average, and 400 W maximum during operation.

5.24.2.3.9 Physical dimensions: The physical dimensions of this instrument are:

a. Sensor head - 0.45 x 0.40 x 0.60 m, 0.1 cu m (stored and operational), and 300 kg in weight.

b. Electronics box - 0.10 x 0.15 x 0.10 m, 0.002 cu m, and 1.5 kg in weight.

5.24.3 Operation

5.24.3.1 Pointing requirements.- The instrument's pointing accuracy will be 1°.

5.24.3.2 Stabilization.- The pointing stability of the instrument will be, at most, 1 deg/sec.

5.24.3.3 Orbiter attitude knowledge.- During instrument operation, the attitude of the Orbiter will be known within 1°.

5.24.3.4 Timeline.- The instrument will operate continuously.

5.24.3.5 Constraints.- Below approximately 400-km altitude, data will be affected due to atmospheric interactions.

5.24.4 Checkout and Test

5.24.4.1 Boresighting requirements.- The instrument will be aligned with respect to its scanning platform, so as to achieve the previously specified pointing accuracy of 1°.

5.24.4.2 Prelaunch checkout.- Prelaunch checkout will include the activation of the low-voltage analog and digital circuits. Housekeeping parameters will be checked. Pulses will be applied to the sensor analog electronics inputs to check gains and discriminator settings. The high-voltage circuits will not be activated at atmospheric pressure.

5.24.4.3 Preflight calibration.- No preflight calibration is required.

5.24.4.4 Inflight calibration.- A two-part calibration sequence will be desirable. First, a pulser will be fed to the input of the sensor's analog electronics and scanned over a range of pulse heights. This will check the counting circuits, but not the sensor. Second, the analyzer will be set to accept a single mass and energy species, and a crude pulse height analysis will be performed by varying either discriminators or gains. The resultant pulse spectrum will indicate the sensor's degradation, if any, and corrections will be applied to the experimental data.

5.24.5 Control

The following commands will be necessary for instrument control:

a. Low-voltage power - on/off

b. High-voltage power - on/off

c. Mode select - Determination has not been made, but will probably require four sequential 8-bit command words or less.

5.24.6 Display

All housekeeping parameters will be displayable upon command. The display for scientific data is to be determined, but will probably consist of an analog display of ion intensity versus energy at a particular mass setting.

5.24.7 Data

5.24.7.1 Scientific.- The scientific data will consist of a serial digital bit stream of the sensor count rates consisting of 8-bit words at 2880 words/second for a total of approximately 23 kbps.

5.24.7.2 Housekeeping.- The housekeeping will be subcommutated and presented as a 0- to 5-V signal to be digitized by the Orbiter into an 8-bit word at 20 words/second for a total of 160 bps.

5.24.8 Development Status

5.24.8.1 Forerunner instruments.- Conceptually similar instruments have flown before and are also currently under development for the GEOS and ISEE satellites. However, none have involved a geometric factor as large as in the present instrument.

5.24.8.2 Problems.- The following subparagraphs discuss the anticipated problems with this instrument.

5.24.8.2.1 Design and manufacturing: The most significant design problem will probably be to attain the rather large geometric factor 1 cm^2 sr. This will require either a mosaic of electron multipliers or channeltrons or else the development of a new type sensor.

5.24.8.2.2 Operational: The particle sensors may be either channeltrons or electron multipliers which will both be sensitive to contamination.

5.25 MEDIUM ENERGY ION MASS ANALYZER (SUBSATELLITE) - INSTRUMENT 540S

5.25.1 Objective

The Medium Energy Ion Mass Analyzer will measure the energy, mass and pitch-angle distribution of ions in the range of 10 eV $\leq E/Q \leq$ 30 keV. It can serve as either a monitor of the natural environment or of ions injected by the Orbiter as tracers.

5.25.2 General Description

5.25.2.1 Location.- This instrument will be mounted on the subsatellite.

5.25.2.2 Configuration.- The instrument will combine energy and mass analysis. Ions entering the instrument will be sorted in energy using an electrostatic analyzer. Following this will be either: (1) a magnetic analyzer composed of a permanent magnet sector with an array of channeltrons along its exit focal plane; or (2) a velocity selector composed of crossed electric and magnetic fields with either a channeltron

or electron multiplier for particle detection. In either case, the energy range will be scanned by varying the voltage across the deflection plates of the electrostatic analyzer. If the mass analysis is method 1, the radii of curvature defined by the channeltron array, along with the energy information, will determine the mass. If the mass analysis is method 2, the crossed electric field will be scanned, and the velocity information, along with the energy determination, will determine the mass. The sensor head will be mounted perpendicular to the subsatellite spin axis.

5.25.2.3 Specifications.- The specifications applicable to this instrument are as follows:

5.25.2.3.1 Energy range: The energy range will be $10 \text{ eV} \leq E/Q \leq 30 \text{ keV}$ where E is the ion energy, and Q is the number of electronic charges on the ion.

5.25.2.3.2 Energy resolution: The energy resolution ($\Delta E/E$) will be 0.1.

5.25.2.3.3 Mass range: The analyzer will be capable of focusing up to 30 keV ions for which $M/Q \leq 16$ where M is the ion mass in atomic mass units, and Q is the number of electronic charges on the ion.

5.25.2.3.4 Mass resolution: The mass resolution $\Delta(M/Q)/(M/Q)$ will be approximately 1/10.

5.25.2.3.5 Data collection rate: The particle sensors will be capable of a counting rate of 10^7 counts/second.

5.25.2.3.6 Field of view: The angular resolution of the instrument is to be determined, but will probably be approximately ±5°.

5.25.2.3.7 Geometric factor: The instrument will have a geometric factor of approximately 0.01 cm^2 sr.

5.25.2.3.8 Power: The electronics box voltage will be 24 Vdc with the standby, average, and maximum power at 10 W each.

5.25.2.3.9 Physical dimensions: The physical dimensions of this instrument are:

a. Sensor head - 0.2 x 0.2 x 0.3 m, 0.01 cu m with a weight of 10 kg.

b. Electronics box - (TBD), 0.005 cu m with a weight of 5 kg.

5.25.3 Operation

5.25.3.1 Pointing requirements.- The instrument's pointing accuracy will be 1°.

5.25.3.2 Stabilization.- The pointing stability will be, at most, 1 deg/sec.

5.25.3.3 Orbiter attitude knowledge.- During instrument operation, the attitude of the subsatellite will be known to within 1°.

5.25.3.4 Timeline.- The instrument will operate continuously.

5.25.3.5 Constraints.- Below approximately 400-km altitude, data will be affected due to atmospheric interactions.

5.25.4 Checkout and Test

5.25.4.1 Boresighting requirements.- The instrument will be aligned with respect to the satellite to acheive the previously specified pointing accuracy of 1°.

5.25.4.2 Prelaunch checkout.- Prelaunch checkout will include the activation of the low-voltage analog and digital circuits. Housekeeping parameters will be checked. Pulses will be applied to the sensor analog electronics inputs to check gains and discriminator settings. The high-voltage circuits will not be activated at atmospheric pressure.

5.25.4.3 Preflight calibration.- No preflight calibration is required.

5.25.4.4 Inflight calibration.- A two-part calibration sequence will be desirable. First, a pulser will be fed to the input of the sensor's analog electronics and scanned over a range of pulse heights. This will check the counting circuits, but not the sensor. Second, the analyzer can be set to accept a single mass and energy species, and a crude pulse height analysis will be performed by varying either discriminators or gains. The resultant pulse spectrum will indicate the sensor's degradation, if any, and corrections can be applied to the experimental data.

5.25.5 Controls

The following commands will be necessary for instrument control:

a. Low-voltage power - on/off

b. High-voltage power - on/off

c. Mode select - the method of implementing the mode select function is to be determined, but will probably require four sequential 8-bit command words or less.

5.25.6 Displays

All housekeeping parameters will be displayable upon command. The display for scientific data is to be determined, but will probably consist of an analog display of ion intensity versus energy for a particular mass setting.

5.25.7 Data

5.25.7.1 Scientific.- The scientific data will consist of a digital bit stream of the sensor count rates consisting of 8-bit words at 3200 words/sec for a total of approximately 25.6 kbps.

5.25.7.2 Housekeeping.- One housekeeping channel will be subcommutated and presented as a 0- to 5-V analog signal to be digitized by the spacecraft into an 8-bit word at 10 words/second for a total of 80 bps. Three other analog channels will be presented to subsatellite telemetry for digitization at 1 sps per channel for a total of 24 bps.

5.25.8 Development Status

5.25.8.1 Forerunner instruments.- Conceptually similar instruments have flown and are presently under development for the GEOS and ISEE satellites.

5.25.8.2 Problems.- No design or manufacturing problems are anticipated. However, the particle sensors will be either channeltrons or electron multipliers, both of which will be sensitive to contamination.

5.26 ENERGETIC ION DETECTOR - INSTRUMENT 541P

5.26.1 Objective

The Energetic Ion Detector will define the energy spectrum and angular distribution of ambient or Orbiter-injected positive ions in the energy range from 20 keV to 10 MeV.

5.26.2 General Description

5.26.2.1 Location.- This instrument will be mounted on the pallet.

5.26.2.2 Configuration.- The Energetic Ion Detector will utilize 17 solid-state detector telescopes of various acceptance geometrics mounted in an angular array on a pallet. Each telescope will be comprised of two or more solid-state detectors whose active areas will constitute a more or less active collimation of the incident particle flux. Data readout from the unit will correlate the energy and angle of incidence of the impinging particle field.

5.26.2.3 Specifications.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.26.2.3.1 Energy range: The energy range will be 20 keV to 10 MeV.

5.26.2.3.2 Energy resolution: Each telescope will output 128 energy channels. The channel width is to be determined.

5.26.2.3.3 Dynamic range: The dynamic range is yet to be determined, but will probably be up to 10^5 to 10^6 counts/second.

5.26.2.3.4 Geometric parameters: The approximate geometric factors, acceptance angles, and aperture areas will be as follows:

Array	A1	A2	A3
Number of telescopes	7	7	3
Acceptance angle, deg	10	20	60
Geometric factor, cm^2 sr	0.001	0.1	10
Aperture area, sq cm	0.04	1	10

Array A1 will have its detectors' view axes distributed in a plane at 25 to 30° intervals. Array A 2 will be in a separate plane parallel to A1 with 25 to 30° view axes separation. Array A3 will be parallel to A2 with its detectors' view axes separated by 60°. The three arrays will be mounted on a scanning platform, such that they can be scanned through 220° of motion.

5.26.2.3.5 Power: The instrument will operate on 28 Vdc. The standby, average, and maximum powers required will each be 10 W.

5.26.2.3.6 Physical dimensions: The linear dimensions are to be determined, but the size and weight will be 0.02 cu m and 15 kg, respectively.

5.26.3 Operation

5.26.3.1 Pointing requirements.- The pointing accuracy will be 1°.

5.26.3.2 Allowable orbiter rate.- The allowable Orbiter rate will be no greater than 1 deg/sec.

5.26.3.2 Orbiter attitude knowledge.- The Orbiter attitude will be known within 1°.

5.26.3.3 Timeline.- The instrument operation period will be continuous. The standby period will be negligible.

5.26.3.4 Constraints.- The detector assembly should be kept in the temperature range -10° to +20° C with a nominal temperature of less than +10° C.

5.26.4 Checkout and Test

5.26.4.1 Boresighting requirements.- These will be only as required to meet the 1° pointing accuracy.

5.26.4.2 Prelaunch checkout.- Prelaunch checkout will consist of applying power to the instrument and observing the various housekeeping parameters. Artificial pulses will be introduced at the inputs of the detector analog electronics to check the analog gains and the various discriminator levels.

5.26.4.3 Preflight calibration.- Low-intensity radioactive sources will be used to exercise the solid-state detectors.

5.26.4.4 Inflight calibration.- An inflight calibration sequence will be performed periodically. This sequence will consist of introducing pulses into the inputs of the detector analog electronics and stepping through the various discrimination levels. Weak radioactive sources will be commandable into the telescopes' fields of view for sensor calibration.

5.26.5 Controls

The following commands will be required:

a. Low-voltage on/off - discrete command

b. High-voltage on/off - discrete command

c. Mode select - TBD bit digital command, probably 24 bits or less

5.26.6 Display

It is assumed that critical housekeeping parameters will activate caution and warning logic and will be called up on the computer cathode-ray tube (CRT) display. Scientific data to be displayed are yet to be determined, but will probably consist of an analog display of counts versus energy from a selectable telescope of the telescope array.

5.26.7 Data

5.26.7.1 Scientific.- Count rates from the telescopes will be merged into a single digital data stream of 8-bit words at a frequency of 10^5 words/second, for a total of approximately 800 kbps.

5.26.7.2 Housekeeping.- Housekeeping data will be subcommutated within the instrument electronics and fed to an Orbiter analog-to-digital converter. Twenty channels/sec of 8-bit data will be envisioned for a total rate of 160 bps.

5.26.8 Development Status

5.26.8.1 Forerunner instruments.- Solid-state detector telescopes have flown on Gemini, Apollo, and Skylab missions as well as many satellites with successful results.

5.26.8.2 Problems.- The anticipated problems with this instrument are discussed in the following subparagraphs.

5.26.8.2.1 Design and manufacturing: No major design or manufacturing problems are anticipated. However, some effort will be required to achieve the low-energy limit of 20 keV. Also, a significant fabrication, testing, and calibration effort will be required because of the large number of telescopes (17) on the instrument.

5.26.8.2.2 Operational: The type of solid-state detectors to be utilized may be sensitive to contamination, and precautions may need to be taken to protect them.

5.27 ENERGETIC ION DETECTOR FOR SUBSATELLITE - INSTRUMENT 541S

5.27.1 Objective

The Energetic Ion Detector will define the energy spectrum and angular distribution of ambient or Orbiter-injected positive ions in the energy range from 20 keV to 10 MeV.

5.27.2 General Description

5.27.2.1 Location.- This instrument will be mounted on the subsatellite.

5.27.2.2 Configuration.- The Energetic Ion Detector will utilize seven solid-state detector telescopes mounted in an angular array on a subsatellite. Each telescope will be comprised of two or more solid-state detectors whose active areas will constitute a more or less active collimation of the incident particle flux. Data readout from the unit will correlate the energy and angle of incidence of the impinging particle field.

5.27.2.3 Specifications.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.27.2.3.1 Energy range: The energy range will be from 20 keV to 10 MeV.

5.27.2.3.2 Energy resolution: Each telescope will output 128 energy channels. The channel width is yet to be determined.

5.27.2.3.3 Geometric parameters: The geometric factors, acceptance angles, and aperture areas will be as follows:

a. Acceptance angle - 20°

b. Geometric factor - 0.1 cm^2 sr

c. Aperture area - 1 sq cm

The view axes of the seven telescopes will be arrayed in a plane with an angular separation of 25° to 30°. The array will be mounted on a scanning platform with 220° of scan, if one a three-axes stabilized vehicle. On a spin-stabilized vehicle, the fields of view of the sensor will be arranged to cover all pitch angles relative to the magnetic field.

5.27.2.3.4 Power: The instrument voltage will operate off 28 Vdc. The standby, average, and maximum powers required will be 1 W each.

5.27.2.3.5 Physical dimensions: The linear dimensions are to be determined, but the size is 0.002 cu m and the weight is 1 kg.

5.27.3 Operation

5.27.3.1 Pointing requirements.- The pointing accuracy will be 1°.

5.27.3.2 Stabilization.- The allowable spacecraft rate of a angular change will be no greater than 1 deg/sec.

5.27.3.2 Subsatellite attitude knowledge.- The subsatellite attitude will be known to within 1°.

5.27.3.3 Timeline.- The instrument operation period will be continuous. The standby period will be negligible.

5.27.3.4 Constraints.- The detector assembly will be kept in the temperature range -10° to +20° C with a nominal temperature of less than +10° C.

5.27.4 Checkout and Test

5.27.4.1 Boresighting requirements.- These will be as required to meet the 1° pointing accuracy.

5.27.4.2 Prelaunch checkout.- Prelaunch checkout will consist of applying power to the instrument and observing the various housekeeping parameters. Artificial pulses will be introduced at the inputs of the detector analog electronics to check the analog gains and the various discriminator levels.

5.27.4.3 Preflight calibration.- Low-intensity radioactive sources will be incorporated to calibrate the solid-state detectors.

5.27.4.4 Inflight calibration.- An inflight calibration sequence will be performed periodically. This sequence will consist of introducing pulses into the inputs of the detectors' analog electronics and stepping through the various discrimination levels. Low-level radioactive sources commandable into the detectors' field of view will be incorporated in the instrument.

5.27.5 Controls

The following commands will be required:

a. Low-voltage on/off - discrete command

b. High-voltage on/off - discrete command

c. Mode select - TBD bit digital command (probably 24 bits or less).

5.27.6 Display

It is assumed that critical housekeeping parameters will activate caution and warning logic and can be called up on the computer cathode-ray tube (CRT) display. Scientific data to be displayed are to be determined, but will probably consist of an analog display of counts versus energy from a selectable telescope of the telescope array.

5.27.7 Data

5.27.7.1 Digital .- Count rates from the telescopes will be merged into a single digital data stream of 8-bit words at a frequency of 120 words/second for a total of approximately 1 kbps.

5.27.7.2 Analog.- Housekeeping data will be subcommutated within the instrument electronics and fed to a subsatellite analog-to-digital converter. Five channels/second of 8-bit data will be envisioned for a total rate of 40 bps.

5.27.8 Development Status

5.27.8.1 Forerunner instruments.- Solid-state detector telescopes have flown on the Gemini, Apollo, and Skylab missions, as well as many satellites with successful results.

5.27.8.2 Problems.- The problems associated with this instrument are discussed in the following subparagraphs.

5.27.8.2.1 Design and manufacturing: No major design or manufacturing problems are anticipated. However, some effort will be required to achieve the lower energy limit of 20 keV. A significant effort will be required for the fabrication, testing, and calibration of the instrument because of the large number (seven) of telescopes involved.

5.27.8.2.2 Operational: The solid-state detectors utilized may be subject to contamination. If so, some means must be implemented for their protection.

5.28 MEDIUM ENERGY ION DETECTOR - INSTRUMENT 542P

5.28.1 Objective

The Medium Energy Ion Detector will measure the energy and pitch angle distribution of ions in the range of 10 eV $\leq E/Q \leq$ 50 keV. It can be used to monitor the natural ion environment or the injected ions used as tracers.

5.28.2 General Description

5.28.2.1 Location.- This instrument will be mounted on the pallet.

5.28.2.2 Configuration.- The instrument will consist of three electrostatic analyzers. This type of analyzer will consist of two curved plates of different radii, mounted parallel to each other with a common center of curvature. Equal but opposite polarity voltages will be placed across the plates with the outer plate being positive. For a given voltage across the plates, ions entering the gap between them with the proper energy and orientation will describe circular paths and will be detected at the exit aperture by an electron multiplier or channeltron array. The energy range of ions accepted will be determined by scanning the voltage across the plates. The three sensors will be mounted with the axes of their apertures in a plane spaced at a to be determined position with respect to each other. The array will be pallet mounted on a scanning platform, such that this plane can be scanned through at least 180°.

5.28.2.3 <u>Specifications</u>.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.28.2.3.1 Energy range: The energy range of this instrument will be from 10 eV $\leq$ E/Q $\leq$ 50 keV.

5.28.2.3.2 Energy resolution ($\Delta E/E$): The energy resolution will be approximately 0.1 (programmable over 64 energy steps).

5.28.2.3.3 Sensitivity: The sensitivity of this instrument is yet to be determined.

5.28.2.3.4 Field of view: The field of view is as follows:

a. The angular resolution of the analyzer will be approximately 10°.

b. The analyzer will scan in pitch angle using the onboard scan platform.

5.28.2.3.5 Geometric factor: The geometric factor will be approximately 1.0 cm^2 sr.

5.28.2.3.6 Dynamic range: The sensor will count to 10^7 counts/sec.

5.28.2.3.7 Power: The power requirements will be:

a. Sensor head - voltage 28 Vdc; standby, average, and maximum power levels will each be 5 W.

b. Electronics box - voltage 28 Vdc; standby, average, and maximum power levels will each be 5 W.

5.28.2.3.8 Physical dimensions: The linear dimensions are yet to be determined, but the physical characteristics of size and weight are as follows:

Size:

a. Sensor heads - 0.25 cu m and 8 kg.

b. Electronics box - 0.002 cu m and 3 kg.

5.28.2.3.9 <u>Contamination</u>.- The instrument will use either electron multipliers or channeltrons as particle sensors. Both of these will be susceptible to contamination.

5.28.3 Operation

5.28.3.1 Pointing requirements.- The pointing accuracy of the instrument will be 1°.

5.28.3.2 Stabilization.- No stabilization requirements are applicable to this instrument.

5.28.3.3 Allowable orbiter rate.- The allowable Orbiter rate will be 1 deg/sec.

5.28.3.4 Orbiter attitude knowledge.- The Orbiter attitude will be known within 1°.

5.28.3.5 Timeline.- Instrument operation will be continuous with negligible standby periods.

5.28.3.6 Constraints.- There are no constraints on this instrument or its operation.

5.28.4 Checkout and Test

5.28.4.1 Boresighting requirements.- These are only as required to meet the 1° pointing accuracy.

5.28.4.2 Prelaunch checkout.- Prelaunch checkout will consist of activating the low-voltage analog and digital portions of the electronics, with subsequent checking of housekeeping parameters, the sensor amplifying system, and digital sequencing and counting circuits. Operation of the high-voltage circuits will be precluded at atmospheric pressure.

5.28.4.3 Preflight calibration.- No preflight calibration is necessary.

5.28.4.4 Inflight calibration.- A two-part calibration sequence will be desirable. First, a pulser will be fed to the input of the sensor's electronics and scanned over a range of pulse heights. This will check the counting circuits but not the sensor. Second, the analyzer can be set to accept a single energy, and a crude pulse height analysis will be performed by varying either discriminators or gains. The resultant pulse spectrum will indicate the sensor's degradation, if any, and corrections can be applied to the experimental data.

5.28.5 Controls

The following commands will be required:

a. Low voltage - on/off

b. High voltage - on/off

c. Mode control - TBD bit command word, probably 24 bits or less

5.28.6 Displays

Housekeeping parameters will be displayable on the cathode-ray tube (CRT) upon command. The scientific data displayed will probably consist of four CRT analog traces (correlated in time) of the sensor count rates versus voltages applied to the analyzer plates.

5.28.7 Data

5.28.7.1 Scientific.- The scientific data will be a serial digital stream of 8-bit words at 30,000 words/second for a total of approximately 250 kbps.

5.28.7.2 Housekeeping.- Housekeeping data will be subcommutated inside the instrument and will be output as a 0- to 5-V analog signal to be converted to an 8-bit digital word by an Orbiter analog-to-digital converter. These words will occur at 10 words/second for a bit rate of 80 bps.

5.28.8 Development Status

5.28.8.1 Forerunner instruments.- Although electrostatic energy analyzers have been flown with considerable success, one with a geometric factor as large as the proposed instrument will probably require some new design effort.

5.28.8.2 Problems.- The problems anticipated with this instrument are discussed in the following subparagraphs.

5.28.8.2.1 Design and manufacturing: The primary design problem will be achieving the geometric factor stated in a preceding paragraph.

5.28.8.2.2 Operational: The particle sensors will be susceptible to contaminants and must be protected.

5.29 MEDIUM ENERGY ION DETECTOR FOR SUBSATELLITE - INSTRUMENT 542S

5.29.1 Objective

The Medium Energy Ion Detector for the subsatellite will measure the energy and pitch angle distribution of ions in the range of 10 eV $\leq$ E/Q $\leq$ 50 keV. It can be used to monitor the natural ion environment or the injected ions used as tracers.

5.29.2 General Description

5.29.2.1 Location.- This instrument will be mounted on the subsatellite.

5.29.2.2 Configuration.- This instrument will perform energy analysis of positive ions utilizing an electrostatic analyzer. This configuration will consist of two curved plates of different radii placed one inside the other with a common center of curvature. For a given voltage across the plates, ions entering the gap with the proper energy and orientation will describe circular paths between the plates and will be detected by an electron multiplier of channeltron array. The energy range will be selected by scanning the voltage across the plates.

5.29.2.3 Specifications.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.29.2.3.1 Energy range: The energy range will be 10 eV $\leq$ E/Q $\leq$ 50 keV.

5.29.2.3.2 Energy resolution ($\Delta E/E$): The energy resolution will be approximately 0.1 (programmable over 64 energy steps).

5.29.2.3.3 Sensitivity: The instrument sensitivity is yet to be determined.

5.29.2.3.4 Field of view: The angular resolution of the analyzer will be approximately 10°. The analyzer will scan in pitch angle using the spin of the satellite or an onboard scan platform.

5.29.2.3.5 Geometric factor: The geometric factor will be approximately 0.5 cm^2 sr.

5.29.2.3.6 Dynamic range: The sensor will count to 10^6 to 10^7 particles/second.

5.29.2.3.7 Power: The power requirements will be:

a. Sensor head - voltage: 28 Vdc; standby, average, and maximum power levels will each be 2 W.

b. Electronics box - voltage: 28 Vdc; standby, average, and maximum power levels will each be 3 W.

5.29.2.3.8 Physical dimensions: The physical characteristics of size and weight are as follows:

a. Sensor head - 0.10 cu m and 8 kg.

b. Electronics box - 0.002 cu m and 1.5 kg.

5.29.2.3.9 Contamination: The instrument will use either electron multipliers or channeltrons as particle sensors. Both of these are susceptible to contamination.

5.29.3 Operation

5.29.3.1 Pointing requirements.- The pointing accuracy of the instrument will be 1°.

5.29.3.2 Stabilization.- See spacecraft rate and attitude requirements.

5.29.3.3 Allowable spacecraft rate.- The allowable spacecraft rate will be 1 deg/sec.

5.29.3.4 Spacecraft attitude knowledge.- The spacecraft attitude will be known within 1°.

5.29.3.5 Timeline.- Instrument operation will be continuous with negligible standby periods.

5.29.3.6 Constraints.- Below 400 km, the data will be affected by atmospheric interactions.

5.29.4 Checkout and Test

5.29.4.1 Boresighting requirements.- These will be only as required to meet the 1° pointing accuracy.

5.29.4.2 Prelaunch checkout.- Prelaunch checkout will consist of activating the low-voltage analog and digital portions of the electronics, with subsequent checking of housekeeping parameters, the sensor amplifying system, and digital sequencing and counting circuits. Operation of the high-voltage circuits will be precluded at atmospheric pressure.

5.29.4.3 Preflight calibration.- No preflight calibration of this instrument is required.

5.29.4.4 Inflight calibration.- A two-part calibration sequence will be desirable. First, a pulser will be fed to the input of the sensor's electronics and scanned over a range of pulse heights. This will check the counting circuits but not the sensor. Second, the analyzer will be set to accept a single energy, and a crude pulse-height analysis will be performed by varying either discriminators or gains. The resultant pulse spectrum will indicate the sensor's degradation, if any, and corrections will be applied to the experimental data.

5.29.5 Controls

The following commands will be required:

a. Low voltage - on/off

b. High voltage - on/off

c. Mode control - TBD bit command word, probably 24 bits or less.

5.29.6 Displays

Housekeeping parameters will be displayable on a cathode-ray tube (CRT) upon command. The scientific data displayed will probably consist of two CRT analog traces (correlated in time) of the sensor count rate and voltage applied to the analyzer plates.

5.29.7 Data

5.29.7.1 Scientific.- The scientific data will be a serial digital stream of 8-bit words at 1600 words/second for a total of 12.8 kbps.

5.29.7.2 Housekeeping.- Housekeeping data will be subcommutated inside the instrument and will be output as a 0- to 5-V analog signal to be converted to an 8-bit digital word by a spacecraft analog-to-digital converter. These words will occur at 10 words/second for a bit rate of 80 bps.

5.29.8 Development Status

5.29.8.1 Forerunner instruments.- Although electrostatic energy analyzers have been flown with considerable success, one with a geometric factor as large as the proposed instrument will probably require some new design effort.

5.29.8.2 Problems.- The problems anticipated with this instrument are discussed in the following subparagraphs.

5.29.8.2.1 Design and manufacturing: The primary design and manufacturing problems will be the achievement of the large geometric factor stated in the preceding paragraph.

5.29.8.2.2 Operational: The particle sensors will be either channeltrons or electron multipliers both of which are sensitive to contaminants.

5.30 ENERGETIC ELECTRON DETECTOR - INSTRUMENT 543P AND 543S

5.30.1 Objective

The Energetic Electron Detector will measure the energy distribution function of electrons from 15 keV to 3 MeV and determine their direction, especially in the auroral regions.

5.30.2 General Description

5.30.2.1 Location.- An array of four sensors will be located on the pallet (543P) and one sensor on a subsatellite (543S).

5.30.2.2 Configuration.- On the pallet, the sensors will be arrayed in a fan shape with the sensors 45° apart. The fan will scan in pitch over the full available clear area, approximately 220° or more at the rate of 1 Hz. This scan will include viewing the magnetic flux lines in one direction, scanning so as to view them in the opposite direction and 20° on each side. The 220° scan will be made on the side away from the earth. Controlling the orientation of the Orbiter will be necessary to achieve this scan. In addition, the array will be capable of rotating upon an axis at right angles to the fan.

On the satellite, the look direction will be controllable in pitch and azimuth.

The configuration of each sensor to be determined. The energy analysis will be performed either via magnetic separation or energy discrimination or both.

For magnetic analysis, the beam will be collimated by baffles. The electrons will be separated into a spectrum by the magnetic field according to their energies. Either 42 solid-state counters or scintillation/photomultiplier counters will be used to detect the electrons in the various ranges. In addition, pulse height discrimination may be used to require that the energy be coincident with that indicated by the magnetic field. This may help to eliminate false counts, such as caused by cosmic rays.

Alternately, solid-state detectors will be arranged along a line called a "telescope." Coincidence will be required to eliminate stray background. The greater the energy, the more total ionization will be produced. Thus, pulse height discrimination will be used to measure the energy. The number of energy bins will be 42.

Electric and magnetic field measurements will be necessary to interpret the data.

5.30.2.3 Specifications.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.30.2.3.1 Energy range: The energy range will be 15 keV to 3 MeV in 42 steps.

5.30.2.3.2 Resolution: If the energy bins are spread logarithmically over the range, the separation between bins will be 13 percent of the energy. Exact resolution is yet to be determined.

5.30.2.3.3 Sensitivity: Individual electrons can be detected. The effective sensitivity will be determined by the area and acceptance angle.

5.30.2.3.4 Field of view and geometric factor: The field of view of each sensor will be approximately 20° across, the geometric factor approximately 10^{-1} cm^2 sr, and the entrance area approximately 1 sq cm.

5.30.2.3.5 Data collection rate: This rate will be estimated at a total of 12,000 sps (samples per second) for the four sensors of the pallet and 126 sps for the subsatellite system.

5.30.2.3.6 Power: The power will be 8 W (at 28 V) per sensor head or 32 W total for the pallet and 8 W for the subsatellite. Of this, 6 W will be for the sensor head and 2 W for the electronics. In addition, a high-voltage shield (1500 to 2500 V) may be needed for each sensor. This will not include the power required to point the instrument.

5.30.2.3.7 Physical dimensions: The exact dimensions are yet to be determined. However, preliminary estimates of size and weight are as follows:

a. Size: 5.8×10^{-3} cu m (each sensor), 0.03 cu m (total volume when mounted as a fan)

b. Weight: 10 kg (each sensor), 40 kg (total for pallet mounted sensors). This weight does not include the weight of the scanning mechanism.

5.30.2.3.8 Temperatures: The instrument will operate best at -10° to +10° C because of the characteristics of solid-state detectors. They will be automatically turned off above 40° C.

5.30.3 Operation

5.30.3.1 Pointing requirements.- The pointing accuracy will be within 1° and the attitude information within 1°.

5.30.3.2 Stabilization.- The maximum angular rate is 1 deg/second.

5.30.3.3 Timeline.- The energy range will be selected using 42 bins. The instrument will scan through 220°.

5.30.3.4 Constraints.- The solid-state detectors will operate best in the range of -10° to +10° C.

5.30.4 Checkout and Test

5.30.4.1 Boresighting requirements.- The boresight check will assure alignment with the Orbiter attitude control to obtain the 1° pointing accuracy and 1° attitude knowledge during flight.

5.30.4.2 Prelaunch checkout.- A radioactive electron source may be used to check performance if the instrument can operate in air. Electrical checks will be made including pulses injected at the output of detectors.

5.30.4.3 Preflight calibration.- Single particles will be detectable, so it is partly self-calibrating. A radioactive source will be used to check the detection efficiency if the detectors can operate in air.

5.30.4.4 Inflight calibration.- A beta ray source will be moved in front of the instrument. More than one may be required to cover the energy range. Internal self-checking electronics will check the circuitry at the commanded times.

5.30.5 Controls

The controls will include voltage on/off and scan on/off. Tentatively, two 32-bit words should be sufficient for mode selection.

5.30.6 Displays

The readout will be programmable in angle and energy using 42 energy levels.

5.30.7 Data

5.30.7.1 Scientific.- The data rate will be 100 kbps at 8-bits per word for the pallet-mounted instrument and 1 kbps for the subsatellite-mounted instrument.

5.30.7.2 Housekeeping.- The housekeeping monitor will be subcommutated, analog, 0 to 5 V, 20 sps for the pallet and 5 to 10 sps for the subsatellite, probably to be converted to digital 8-bit words.

5.30.8 Development Status

5.30.8.1 Forerunner instruments.- Instruments using solid-state telescopes have flown on Skylab and other satellites. All subsystems have either flown before or are within the state-of-the-art.

5.30.8.2 Problems.- Anticipated problems with this instrument are discussed in the following subparagraphs.

5.30.8.2.1 Design and manufacturing: The instrument has not yet had a detailed analysis or optimization. Because state-of-the-art techniques will be used, no difficulties are anticipated.

5.30.8.2.2 Operational: If the instrument uses magnetic analysis, the stray magnetic field may affect other charged particle sensors which will detect lower energy particles; also, the sensor for measuring the magnetic field may be affected.

5.31 MEDIUM ENERGY ELECTRON DETECTOR - INSTRUMENT 544

5.31.1 Objective

The Medium Energy Electron Detector will measure the energy distribution function of electrons in the range from 10 eV to 50 keV and the direction from which they come. Under certain conditions, electrons in this energy range will be the primary source of energy in the upper atmosphere.

5.31.2 General Description

5.31.2.1 Location.- This instrument will be mounted on the pallet.

5.31.2.2 Configuration.- Ten sensors will be arranged in a fan-shaped array 10° apart. The array will scan 180° in pitch angle. The array will be located on a boom at least 45 meters from the Orbiter.

Each sensor will have a sunshade which will eliminate solar background counts when the sun is outside the field of view. It will contain a series of geometrically spaced window frame baffles with knife edges, which will prevent direct sunlight from entering the analyzer for angles greater than a off-axis angle yet to be determined.

An aperture will define the entrance area to the analyzer.

The analyzer will consist of two concentric plates each of which will be part of a cylinder. Voltages of equal magnitude and opposite polarity will be applied to the plates with the positive plate being the inner one. Electrons with energies greater than a certain energy band will strike the outer plate, and those with energies less than the band will strike the inner plate. Electrons with energies in the band will pass through to the detector. The radius of curvature of the arc midway between the plates and the separation of the plates will be selected so that the width of the energy band which passes will be 10 percent of the center energy. The energy of the passband will be an order of magnitude greater than the applied voltage. The ratio of the voltage associated with the center of the passband to the applied voltage will also be determined by the geometry. The analyzer plates will be fabricated of beryllium, which will be used to minimize electron scattering.

The detector will be an open-window electron multiplier with a continuous dynode surface requiring a voltage of approximately 4000 V along its axis for a gain of 10^8. At this gain, the response will saturate and the pulse will be 20 times the threshold for counting electrons. Thus, considerable degradation in gain must occur before the counting is affected. However, the quantum efficiency of the first surface can be affected by contamination, and changes can occur due to adsorbed gases.

5.31.2.3 Specifications.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.31.2.3.1 Energy range: The energy range will be from 10 eV to 50 keV, covered by probably two instrumental ranges.

5.31.2.3.2 Sensitivity: This will be the response to individual electrons with a maximum counting rate of 10^7 per second.

5.31.2.3.3 Field of view: The field of view will be 10° for each unit. The geometric factor, or product of entrance area multiplied by the acceptance solid angle, will be 10^{-2} cm^2 sr.

5.31.2.3.4 Data collection rate: The data rate will tentatively be 16 or 64 sps per second, probably programmable.

5.31.2.3.5 Power: The power will be 8 W per sensor (10 sensors), for a total of 80 W, maximum and average, at 28 V.

5.31.2.3.6 Physical dimensions: The physical characteristics of size and weight of this instrument are estimated to be 0.006 cu m (total) with each sensor estimated to be 20 cm long and 5 cm diam curved in a 60° arc. The total weight for the instrument is estimated as 5 kg.

5.31.3 Operation

5.31.3.1 Pointing requirements.- The required pointing accuracy will be 1°, and the attitude information required will be 1°.

5.31.3.2 Stabilization and tracking requirements.- The maximum angular rate will be 1 deg/sec.

5.31.3.3 Timeline.- The integration time and energy range, or a sequence of these, will be selected. Scan will begin at a rate yet to be determined. The low voltages will be activated, and after warmup, the high voltage will be applied with the recording of data. The number

of energy steps will be programmable, but typically a maximum of 64 in logarithmic steps. If the gain of the multiplier decreases, its voltage may be increased.

5.31.3.4 Constraints.- The sensors cannot view the sun without the multiplier voltage being turned off.

5.31.4 Checkout and Test

5.31.4.1 Boresighting requirements.- Boresight check must be adequate to assure 1° pointing accuracy.

5.31.4.2 Prelaunch checkout.- The prelaunch checkout will be limited to checks which will not involve turning on the high voltage.

5.31.4.3 Preflight calibration.- No calibration is expected to be feasible.

5.31.4.4 Inflight calibration.- No complete calibration will exist. In a region of an approximately constant count rate, the discrimination for the pulse height will run through the eight threshold levels, and the differences in indicated flux will be found to obtain differential counting rates between thresholds. From this spectrum, a comparison will be made with previous spectra to determine the status of the detector. As the detector degrades and by knowing the exact status of the spectrum, it will be possible to normalize the resultant data. Also, the input frequency of the simulated signal will vary from 16 to 128 kHz to check for frequency effects.

5.31.5 Controls

Two 32-bit mode commands and two power-control relays will be used; the same commands will be given to all 10 sensors.

5.31.6 Displays

A scope will be switched among the 10 sensors and will be shared with other instruments. A numerical readout will be programmable for any of the 64 energy steps.

5.31.7 Data

5.31.7.1 Scientific.- These data will be digital at sixty-four 8-bit words/second for 512 bits per sensor or 5120 bps for 10 sensors.

5.31.7.2 Housekeeping.- These data will be analog at 0 to 5 V with 8-bit words at a rate yet to be determined (estimated not over 10 per 8 seconds) for each sensor.

5.31.8 Development Status

5.31.8.1 Forerunner instruments.- Similar instruments have flown on Atmosphere Explorer (AE) C and D.

5.31.8.2 Problems.- No design or manufacturing problems are anticipated. Contamination will be a likely problem during the operational phase. At the lowest energies, electrical and magnetic interference may cause false readings.

5.32 PLASMA ACCELERATOR (SEPAC) - INSTRUMENT 546

5.32.1 Objective

The Space Experiment with Plasma Accelerators (SEPAC) system will provide high-intensity pulsed plasma and electron beams. It will be utilized to modify ionospheric parameters and excite artifical airglow, to perturb the magnetospheric particle population, and for general and applied plasma physics experiments in space.

5.32.2 General Description

5.32.2.1 Location.- This instrument will be mounted on a pallet or a subsatellite.

5.32.2.2 Configuration.- SEPAC will consist of three particle accelerators: (1) a plasma accelerator, (2) a high-energy pulsed electron accelerator, and (3) a low-energy dc electron accelerator.

5.32.2.2.1 Plasma accelerator: The plasma accelerator will be either in the form of a bank of 10 to 20 coaxial plasma guns or magnetoplasmadynamic (MPD) arcs. In either case, Orbiter 28 Vdc power will be converted to high-voltage dc (10 kV maximum for the high-voltage plasma gun or 500 V maximum for the MPD arc) by a voltage converter, and the output of the converter will feed a 60 kJ capacitor bank which will store electrical energy for high-intensity pulsed operation. Neutral gas, of the plasma species desired, will be fed pulsively by an electrical fast-acting valve into the plasma gun. At a predetermined pressure, which will occur about 300 μs after initiation of gas flow, the negative output of the capacitor bank will be applied to the cathode of the plasma

gun, creating a high-intensity discharge in the gun resulting in the expulsion of a plasma of ions and electrons. The guns in the bank may be fired either sequentially or in parallel depending on experimental objectives.

5.32.2.2.2 Electron accelerator (high energy): The electron accelerator will be very high-intensity, pulsed electron source. It will derive its accelerating voltage from the same capacitor bank which will feed the plasma gun during the charging interval of the bank between plasma bursts. As a result, the energy of the electron beam will vary depending on the points in the charging cycle at which the electron gun is pulsed. A return current for vehicle neutralization will be provided by jetting a plume of neutral gas into the electron beam and utilizing the low-energy electrons produced by ionization.

5.32.2.2.3 Electron accelerator (low energy): The low-energy electron accelerator will produce a dc beam of low-energy electrons. Details of its configuration are yet to be determined.

The three accelerators will be mounted on a platform which can be raised to a point outside the Orbiter bay and rotated about one axis for pointing purposes.

Proper diagnosis of the phenomena generated by the SEPAC accelerators will require instrumentation for detecting high- and low-frequency electromagnetic waves, spectroradiometric instrumentation (ultraviolet (UV), infrared (IR), visible), plasma probes (e.g., Langmuir probe), particle detectors (ion and electron), and a magnetometer.

5.32.2.3 <u>Specifications</u>.- The specifications applicable to these instruments are delineated in the following subparagraphs.

5.32.2.3.1 Plasma accelerator bank:

a. Ion energy: 10 to 200 eV (MPD arc), 100 to 1000 eV (high-voltage plasma gun).

b. Ion and electron temperature: approximately 10 eV.

c. Particles per shot: approximately 10^{20} (parallel gun operation).

d. Pulse duration: 10 ms (MPD arc), 10 μs (high-voltage plasma gun).

e. Repetition rate: 1 burst per 60 seconds to 1 burst per 10 seconds (parallel gun operation).

f. Output energy per burst: 10 kJ (parallel gun operation).

g. Capacitor storage bank: 60 kJ.

h. Beam angular divergence: ±30°.

5.32.2.3.2 Electron accelerator (high energy):

a. Electron energy: 10 keV (maximum)

b. Current: 1000 A (maximum)

c. Pulse width: 10 μs (minimum)

d. Repetition rate: approximately 3 pulses/second (may be variable)

e. Output energy: 100 J per pulse.

f. Beam angular divergence: TBD

5.32.2.3.3 Electron accelerator (low energy):

a. Electron energy: less than 10 eV.

b. Current: determined by surrounding medium.

c. Operation mode: dc

d. Beam angular divergence: TBD.

5.32.2.3.4 Power: The power requirements are 28 Vdc and 40 W during standby operation, 1 kW average and 5 kW maximum during operation.

5.32.2.3.5 Physical dimensions: The physical characteristics of size and weight are as follows:

a. Plasma accelerator - 1.0 x 1.0 x 1.0 m, 1.0 cu m and 1000 kg.

b. Electron accelerators - (TBD), 0.0 cu m (stored), 0.2 cu m (operational) and 100 kg.

c. Control circuits - (TBD), 0.02 cu m and 20 kg.

5.32.3 Operation

5.32.3.1 Pointing requirements.- The pointing accuracy will be 0.5°.

5.32.3.2 Stabilization.- This allowable angular rate of change in pointing will be 0.5 deg/sec.

5.32.3.3 Orbiter attitude knowledge.- The Orbiter attitude will be known to within 0.5°.

5.32.3.4 Timeline.- The operation will be determined by experiment objectives.

5.32.3.5 Constraints.- The allowable operational temperature limits will be -10° to +70°C. Background pressure test requirements will be less than 10^{-6} torr. The pointing of the accelerator's beams with respect to the direction of the ambient magnetic field may not be arbitrary, because of the possibility of beam return and collision with the Orbiter caused by the gyromotion of the beam particles in the field. Depending upon return beam energy and intensity, thermal and vehicle charging problems might be caused. Details of possible pointing constraints are yet to be determined. However, the firing of the accelerators will be restricted by a GO/NO GO command generated by a magnetometer, namely, the Vector Magnetometer (Instrument 548), which will also be on the Orbiter.

5.32.4 Checkout and Test

5.32.4.1 Boresighting requirements.- These will be as required to achieve a 0.5° pointing accuracy.

5.32.4.2 Prelaunch checkout.- Low-voltage subsystems will be activated and housekeeping parameters measured. Various pulse sequencing modes will be initiated and monitored, but high-voltage systems will not be activated at atmospheric pressure.

5.32.4.3 Preflight calibration.- None required.

5.32.4.4 Inflight calibration.- To be determined.

5.32.5 Controls

Most of the sequencing functions will be performed by a sequence-control box built into the accelerator package. However, access to several accelerator parameters and mode changing will be required. These will require a yet to be determined number of 8-bit command words.

5.32.6 Displays

A cathode-ray tube (CRT) display of various accelerator monitoring parameters will be required. The number of parameters will be approximately 17. The number of these to be displayed is yet to be determined.

5.32.7 Data

Monitoring of accelerator parameters will require 17 channels of analog data (0 to 5 V) digitized to 6-bit accuracy and sampled at 2 kHz for a total bit rate of 204 kbps.

5.32.8 Development Status

5.32.8.1 Forerunner instruments.- Plasma guns with the capacity of the SEPAC guns exist as laboratory instruments and a similar plasma gun of less capacity than the SEPAC has flown successfully on a rocket. Electron accelerators of significantly smaller current output have flown on several rockets.

5.32.8.2 Problems.- The anticipated problems with this instrument are discussed in the following subparagraphs.

5.32.8.2.1 Design and manufacturing: Achievement of the 1000 A peak-pulse electron current will require considerable design and development effort.

5.32.8.2.2 Operational: The problem of neutralization of the charge buildup on the Orbiter during electron operation using the method proposed will require study to determine its effectiveness. Also, depending on the construction of the electron source, problems due to contaminants in the payload bay may exist. Possible corona and high-voltage discharge problems may be present, and beam instabilities caused by the interactions with the ambient plasma in the vicinity of the Orbiter are possible.

5.33 ION DRIFT DETECTOR - INSTRUMENT 547

5.33.1 Objective

The Ion Drift Detector will measure the three-axes drift of ionospheric thermal ions at or near the spacecraft at all operational altitudes (200 to 700 km). In addition, analysis of the data will provide

measurements of the ambient ion temperature, total ion concentration, and vehicle potential.

5.33.2 General Description

5.33.2.1 Location.- This instrument will be mounted on a boom or a subsatellite.

5.33.2.2 Configuration.- The instrument, which will utilize three sensor heads, will generally point in the spacecraft ram direction. One head will measure the component of ion-drift velocity which will be parallel to the spacecraft velocity vector. This head will be in the form of a retarding potential analyzer (RPA). In this sensor, ions will enter an aperture and strike a solid collector. The path between the aperture and collector will be segmented by several grids. At a minimum, there will be a grid at the aperture, grounded to the sensor face. Next inward will be the retarding grid whose potential (assumed positive) will determine the minimum energy ion which will traverse it and reach the collector. Between the retarding grid and collector will be a suppressor grid. It will be held at a negative potential, which will be high enough to suppress secondary electrons emitted from the collector and to stop low-energy electrons entering the aperture from reaching the collector. In operation, the voltage on the retarding grid will be varied, and the ion current reaching the collector will be measured. The resultant data will yield an integral curve of ion current versus ion energy from which, by means of curve fitting to a theoretical expression, the desired velocity component will be extracted. In addition, the analysis will also yield the ion temperature, total ion concentration, and vehicle potential. The other two components of the ion drift velocity (perpendicular to the spacecraft velocity vector) will be measured by two similar RPA sensor heads. However, each of these will have a split collector; all grids, with the exception of the negative suppressor grid, will be grounded. If the average entry velocity is perpendicular to the sensor face, the collector segments will receive equal currents. When the velocity is not perpendicular to the collector, the segment currents will become unequal. Knowing the orientation of the sensor head with respect to the spacecraft velocity vector and the aperture and collector geometry, the magnitude of the difference current will yield one of the two perpendicular ion drift velocity components. The other component will be measured by the second split-collector sensor head. Information on the parallel velocity component will be improved if the ion composition can also be measured by a separate ion mass spectrometer. Information on the ion-drift velocity vector from the Ion Drift Detector will be required for pointing particle accelerators and for some chemical release experiments.

5.33.2.3 Specifications.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.33.2.3.1 Energy range: The energy range will be approximately 0 to 35 eV.

5.33.2.3.2 Energy resolution: The energy resolution requirements are yet to be determined.

5.33.2.3.3 Sensitivity: The instrument will be capable of measuring (1) ion concentrations from 500 to 5×10^6 ions/cu cm, (2) velocity measurements with a sensitivity of 20 m/sec, and (3) spatial resolution of 100 m.

5.33.2.3.4 Field of view: The field of view has not yet been determined, but it will probably be greater than 60°.

5.33.2.3.5 Power: The power requirements are 24 Vdc with 0 W in standby, and 6 W average and maximum while operational.

5.33.2.3.6 Physical dimensions: The physical characteristics of size and weight are:

a. Sensor heads 1, 2, and 3 - 0.14 x 0.14 x 0.08 m, 0.0016 cu m each and 1.2 kg each.

b. Electronics box - 0.15 x 0.15 x 0.10 m, 0.0022 cu m and 1.5 kg.

5.33.2.3.7 Electromagnetic interference (EMI): EMI susceptibility and emanation will be negligible.

5.33.3 Operation

5.33.3.1 Pointing requirements.- The sensor heads will be pointed to an accuracy of 0.1° and must face in the ram direction.

5.33.3.2 Stabilization.- The allowable angular rate of change in pointing will be 0.2 deg/sec or less.

5.33.3.3 Spececraft attitude knowledge.- The attitude of the spacecraft will be known to within 1°.

5.33.3.4 Timeline.- Instrument operation will be continuous and will require less than 1 minute standby warmup.

5.33.3.5 Constraints.- The Ion Drift Detector will operate in the region from 200- to 700-km altitude. The operating temperature limits for the instrument will be from -20° to +50° C.

5.33.4 Checkout and Test

5.33.4.1 Boresighting requirements.- These will be as required to achieve the stated 0.1° pointing accuracy.

5.33.4.2 Prelaunch checkout.- Low-voltage power will be applied and housekeeping parameters measured. All control functions will be tested and the various preprogrammed retarding grid voltage sequences checked.

5.33.4.3 Preflight calibration.- A variable precision current source will be fed into the inputs of the current amplifiers to check their calibration.

5.33.4.4 Inflight calibration.- The inflight calibration requirements are yet to be determined.

5.33.5 Controls

The following controls will be required for proper operation of the detectors:

a. Power on/off - one bit

b. Sensor head on/off - three bits

c. Sensitivity range control - six bits

d. Power supply levels - six bits

5.33.6 Displays

A real-time cathode-ray tube (CRT) display of the ion drift velocity vector and the equivalent electric field will be required for the pointing of accelerators and for some chemical release experiments. In addition, a CRT display of the instrument's housekeeping parameters will be available upon command.

5.33.7 Data

The instrument will generate both analog and digital outputs. It is assumed that the spacecraft will supply analog-to-digital converters will digitize the analog (0 to 5 V) signals to 8-bit words. The parameters and their sampling rates will be as follows:

Parameters	Type	Accuracy, bits	Sampling rate, sps	Bit rate, bps
SCIENTIFIC				
SH1[a] current	Analog	8	160	1280
SH1 retarding voltage	Analog	8	160	1280
SH1 sensitivity range	Digital	4	160	640
SH2 diff. ampl. output	Analog	8	80	640
SH2 sensitivity range	Digital	2	80	160
SH3 diff. ampl. output	Analog	8	80	640
SH3 sensitivity range	Digital	2	80	160
HOUSEKEEPING				
SH1 temperature	Analog	8	0.1	0.8
SH1 power supply level	Analog	8	0.1	0.8
SH2 temperature	Analog	8	0.1	0.8
SH2 power supply level	Analog	8	0.1	0.8
SH3 temperature	Analog	8	0.1	0.8
SH3 power supply level	Analog	8	0.1	0.8

Note: [a]SH = sensor head. All data outputs will be routed through the electronics box.

5.33.8 Development Status

5.33.8.1 Forerunner instruments.- RPA's have flown on several satellites (e.g., IMP, OGO, and AE series) with considerable success. The present instrument configuration will be very similar to that flown on the AE series. The instrument will be within the state-of-the-art.

5.33.8.2 Problems.- No problems are anticipated.

5.34 VECTOR MAGNETOMETERS - INSTRUMENT 548

5.34.1 Objective

The Vector Magnetometers will measure the following:

(a) The ambient magnetic field at the spacecraft, which will determine the cyclotron frequencies of various particles;

(b) The orientation of various instruments on the spacecraft (e.g., accelerators, particle detectors, and optical instruments) with respect to the local field direction for the purpose of particle injection, field-line tracing, induced electric fields determination; and

(c) Magnetospheric currents (e.g., Birkeland currents).

5.34.2 General Description

5.34.2.1 Location.- This instrument will be mounted on the boom or subsatellite.

5.34.2.2 Configuration.- The magnetic measurements will be carried out by at least two different types of magnetometers: the alkali-vapor magnetometer and the triaxial fluxgate magnetometer.

5.34.2.2.1 Alkali-vapor magnetometer: In this instrument, light from a cesium lamp will be filtered, circularly polarized, and passed through an absorption cell containing cesium vapor into a photodiode, where it is sensed. The light will excite certain levels in the cesium vapor, and the application of a magnetic field (e.g., earth's magnetic field) will cause an alignment and precision of the magnetic moments of the excited vapor atoms about the applied field with a frequency (Larmor) determined by the magnitude of the applied field. By applying a radio frequency field to the vapor cell at the Larmor frequency, the orientation of the atoms will be destroyed, and the result will be an

increased absorption of light in the cell and a reduction in the light intensity measured by the photodiode. The Larmor frequency will be related to the applied magnetic field by accurately known atomic constants. Hence, by detecting the resonance and measuring the Larmor frequency, the scalar magnitude of the applied magnetic field will be determined absolutely. To make the instrument directional, bias coils, which produce precisely known magnetic fields, will be oriented orthogonally around the vapor cell. The cell will then measure the magnitude of the resultant vector sum of the earth's field and the field from the coils. By exciting one or more coils in sequence and measuring the Larmor frequency at each excitation, the direction angles for the earth's magnetic field vector will be determined by computation.

5.34.2.2.2 Triaxial fluxgate magnetometer: In one of its simpler forms, the fluxgate magnetometer will consist of a small thin rod (core) of high-permeability magnetic material surrounded by two identical excitation coils. The coils will be driven in antiphase with respect to each other by an ac voltage (current) high enough to produce saturation (i.e., if only one coil is energized) in the core. In the absence of any external field, the resultant magnetization in the rod will be zero, and no resultant effect will be observed. If, however, an external field (e.g., the earth's magnetic field) is applied, such that it has a component along the rod, an effect will be produced in the rod which will be coupled back into the excitation coils. Then, a voltage will appear across them which, in the present instrument, will be at the second harmonic of the frequency of the exciting voltage; the amplitude will be proportional to the component of the external field parallel to the rod. By arranging three fluxgates along three orthogonal axes (e.g., triaxial fluxgate), the three components of the external field will be obtained. The triaxial fluxgate will not be an absolute instrument; however, it can be made very stable and repeatable and can be calibrated against an absolute instrument (e.g., cesium vapor magnetometer).

The sensor heads for both of the described magnetometers will be boom mounted, if it is on the Orbiter. Their respective electronics boxes will be pallet mounted. For subsatellite operation, a boom mounting will also be desirable for the sensors.

5.34.2.3 Specifications.- The specifications applicable to these instruments are delineated in the following subparagraphs.

5.34.2.3.1 Range:

a. The range of the cesium vapor instrument will be from less than 0.1 to 10^5 gammas.

b. The range of the triaxial fluxgate instrument will be from less than 5 to 10^5 gammas.

5.34.2.3.2 Resolution:

a. The resolution of the cesium vapor instrument will be approximately 0.05 gammas.

b. The resolution of the triaxial fluxgate instrument will be approximately 1 to 5 gammas.

5.34.2.3.3 Field of view: The field of view will be 4π sr for each instrument.

5.34.2.3.4 Power:

a. The power required for the cesium vapor instrument is 28 Vdc and usage will be 20 W average and 30 W maximum (for less than one-half hour from activation)

b. The power required for the triaxial fluxgate instrument is 28 Vdc and usage will be 20 W average and maximum.

5.34.2.3.5 Physical dimensions: The physical characteristics of size and weight of these instruments

a. Cesium vapor sensor - 0.15 x 0.15 x 0.15 m, 0.0034 cu m, and 0.94 kg.

b. Cesium vapor electronics - 0.15 x 0.2 x 0.2 m, 0.006 cu m, and 2.7 kg.

c. Triaxial fluxgate sensor - 0.13 x 0.08 x 0.08 m, 0.007 cu m, and 0.45 kg.

d. Triaxial fluxgate electronics - 0.18 x 0.18 x 0.15 m, 0.0005 cu m, and 3.64 kg.

5.34.3 Operation

5.34.3.1 Pointing requirements.- The magnetometers will be essentially 4π sr instruments and will have no pointing requirements themselves. What is important is a knowledge of the alignment of the magnetometers' axes with respect to the Orbiter or subsatellite (for ambient field monitoring or detection of magnetospheric currents) or with respect

to the reference platforms of the various instruments (e.g., particle detectors and optical detectors), which will require a knowledge of the magnetic field for effective operation. The basic accuracy of field direction determination of either magnetometer will be no less than 0.01°.

5.34.3.2 Stabilization.- No stabilization requirements will exist for the cesium vapor magnetometer. The triaxial fluxgate will track variations of 30 deg/sec or less.

5.34.3.3 Spacecraft attitude knowledge.- For ambient monitoring, attitude must be known to within 1°. For detection of magnetospheric currents from a subsatellite, the attitude of the subsatellite will be known to within 0.01°.

5.34.3.4 Orbital parameters.- The location of the Orbiter or subsatellite will be known to within ±1 km.

5.34.3.5 Timeline.- The operational period will depend on experimental objectives. The magnetometers may operate continuously for ambient monitoring or may be used only periodically as needed for the pointing of instruments. In either case, the magnetometer will require approximately 30 minutes for stabilization after power activation.

5.34.3.6 Constraints.- The cesium vapor magnetometer sensor head box will be maintained at temperatures between 0° and 50° C. The operational temperature range for the triaxial fluxgate magnetometer is yet to be determined, but will be wider than that for the cesium vapor magnetometer.

Both magnetometers, of course, will be very sensitive to contaminating magnetic fields. Static spacecraft fields with a gradient of less than 10 gammas/cm can be calibrated out, but time-varying fields will contribute an error to the measurement.

5.34.4 Checkout and Test

5.34.4.1 Boresighting requirements.- Depending on the application involved, the magnetometers may have to be boresighted with respect to a particular pointing platform or navigation base to within 0.01°. (See the preceding Pointing Requirements paragraph.)

5.34.4.2 Preflight calibration.- Although no prelaunch calibration will be performed, the ambient earth's magnetic field (possibly distorted by surrounding structures) will automatically be sensed by the instrument and will serve to show that the sensors are functioning.

5.34.4.3 Inflight calibration.- No calibration will exist for the cesium vapor magnetometer. If the triaxial fluxgate is flown at the same time as the cesium vapor magnetometer, an absolute calibration inflight for the fluxgate will be obtained; otherwise, there will be none.

5.34.5 Controls

The following subparagraphs delineate the controls required for proper operation.

5.34.5.1 Cesium vapor magnetometer.- The cesium vapor instrument controls required are:

a. Power on/off - one control (bit)

b. Coil voltages (1,2,3) on/off - three controls (bits)

c. Sample rate - three bits

d. Bias fields - nine bits

5.34.5.2 Triaxial fluxgate.- The triaxial fluxgate instrument controls required are:

a. Power on/off - one bit

b. Sample rate - three bits

c. Bucking field - three bits

d. Analog-to-digital converter scale - one bit

5.34.6 Displays

For ambient field monitoring, a cathode-ray tube (CRT) digital display of the three components of the magnetic field updated once every 10 seconds will be required. For coordination of accelerator beams and optical observation, a real-time CRT display of the magnetic field line (computer-generated) and the field of view of the optical instrument will be required. In addition, a CRT display of housekeeping parameters will be available upon command.

5.34.7 Data

The following data will be generated by the magnetometers:

Cesium Vapor	Type[1]	Amplitude	Word length, bits	Sampling rate	Bit rate
Larmor frequency	D	-	100	10/sec	1 kbps
Cell temperature	A	0-5	8	1/min	8 bpm
Current supply	A	0-5	8	1/min	8 bpm
Bias state	D	-	8	40/sec	0.32 kbps
Electronics temperature	A	0-5	8	1 min	8 bpm

Triaxial fluxgate	Type[1]	Amplitude	Word length, bits	Sampling rate	Bit rate
Axis 1	D	-	16	30/sec	0.5 kbps
Axis 2	D	-	16	30/sec	0.5 kbps
Axis 3	D	-	16	30/sec	0.5 kbps
Electronics temperature	A	0-5	8	1/min	8 bpm
Voltage	A	0-5	8	1/min	8 bpm

Note: [1]A - analog; D - digital; spacecraft analog to digital assumed.

5.34.8 Development Status

5.34.8.1 Forerunner instruments.- Cesium vapor magnetometers have been successfully flown on rockets, and triaxial fluxgate magnetometers have been used extensively on rockets and satellites. Both instruments will be well within the state-of-the-art.

5.34.8.2 Problems.- No design or manufacturing problems are anticipated, but operationally, time varying, spacecraft-created magnetic fields will definitely present a contamination to the measurements unless the magnetometer sensors are located outside of these fields, such as on a boom or subsatellite.

5.35 LEVEL III BEAM DIAGNOSTIC GROUP - INSTRUMENT 551

5.35.1 Objective

The Level III Beam Diagnostics Group will measure the time rate of change of the magnetic field in the electron beam-ambient space plasma system interaction and the electric field and plasma potential variations in this system.

5.35.2 General Description

5.35.2.1 Location.- This instrument will be mounted on a boom.

5.35.2.2 Configuration.- The instrument consists of three probes, which are the Magnetic Flux ($\dot{B}$) probe, the Electric Vector ($\vec{E}$) probe, and the Fast Plasma Potential (V_p) probe. A discussion of each follows.

5.35.2.2.1 $\dot{B}$ Probe: This instrument will measure the time rate of change of the magnetic field induced by electron beam and space plasma interactions. It will take the form of three orthogonal coils a few centimeters in diameter. The voltage induced in each coil will be proportional to the time rate of change of the component of the magnetic field perpendicular to the plane of the coil. By simultaneous measurement of three orthogonal components and proper treatment of the data, the time rate of change of the magnitude of the magnetic field vector will be obtained.

5.35.2.2.2 $\vec{E}$ probe: This probe will measure the electric field vector in the beam-ambient plasma system in the vicinity of the Orbiter. The three orthogonal components of the field will be measured by means of three sets of double floating probes. The double floating probe will consist of two electrodes of small spacial dimensions spaced a few centimeters apart and isolated from the ground. Each probe will come to a potential near the plasma potential at its point of location. The potential difference measured between the two probes divided by their separation will be a measure of the component of the electric field parallel to the line joining the probes.

5.35.2.2.3 Fast V_p probe: The fast V_p probe will measure time variations in the ambient plasma in the vicinity of the Orbiter caused by beam-plasma interactions. This probe will assume the form of a floating probe. The floating probe will be an electrode immersed in the plasma and insulated from the ground, in the present case, the Orbiter ground. The probe will assume a potential near the plasma potential. If the probe is capacitively coupled into a potential measuring device, the measuring device will respond to the time variations of the probe potential.

The three probes will be mounted on a 2-m boom along with the Level II Beam Diagnostics (see Instrument 550) and will be extended outside of the Orbiter bay using the Remote Manipulator System (RMS). If the RMS cannot be used, a dedicated boom will be required for deployment of the Level I and Level II diagnostics.

5.35.2.3 Specifications.- The specifications applicable to these three instruments are delineated in the following subparagraphs.

5.35.2.3.1 Measurement range: The measurement range of the three instruments is:

a. $\dot{B}$ Probe: 2 x 10^{-3} webers/sq m/sec to 2 webers/sq m/sec.

b. $\vec{E}$ Probe: 10 μV/m to 10 V/m.

c. Fast V_p Probe: 1 V peak (maximum).

5.35.2.3.2 Frequency response (bandwidth): The frequency response of the three instruments is:

a. $\dot{B}$ Probe: 0 to 10 MHz.

b. $\vec{E}$ Probe: 0 to 100 MHz.

c. Fast V_p Probe: less than or equal to 10 MHz.

5.35.2.3.3 Field of view: The field of view will be essentially 4π sr.

5.35.2.3.4 Power: The power required is 28 Vdc with 5 W used in standby and 10 W average and 20 W maximum while operating.

5.35.2.3.5 Physical dimensions: The physical characteristics of the three instruments are:

a. Size: $\dot{B}$ Probe, $\vec{E}$ Probe, and Fast V_p Probe - 0.1 x 0.1 x 0.1 m, 0.001 cu m.

b. Weight: $\dot{B}$ Probe, $\vec{E}$ Probe, and Fast V_p Probe - 5 kg

5.35.3 Operation

5.35.3.1 Pointing requirements.- The probes will be capable of being pointed to within 3° of a magnetic field line.

5.35.3.2 Stabilization.- The rate of angular change of pointing will be 1 deg/sec or less.

5.35.3.3 Orbiter attitude knowledge.- The attitude of the Orbiter will be known within 3°.

5.35.3.4 Timeline.- The operational period will be approximately 4 hours/day during particle accelerator operations.

5.35.3.5 Constraints.- There are no operational constraints.

5.35.4 Checkout and Test

5.35.4.1 Boresighting requirements.- These will be only as required to meet the 3° pointing accuracy.

5.35.4.2 Prelaunch checkout.- The low-voltage subsystem will be activated and housekeeping parameters checked.

5.35.4.3 Preflight calibration.- No preflight calibration is required.

5.35.4.4 Inflight calibration.- Probably no inflight calibration will be required.

5.35.5 Controls

The method of signal conditioning from the sensors is yet to be determined. This method may require analog line drivers located at the

sensor heads with bandwidth selection. If so, the sensor electronics heads will require the following controls:

a. Power on/off - one bit.

b. $\dot{B}$ Probe:

Frequency select - three bits

Gain select - three bits

c. $\vec{E}$ Probe:

Frequency select - six bits

Gain select - three bits

d. Fast V_p Probe:

Frequency select - three bits

Gain select - three bits

5.35.6 Displays

A real-time simultaneous analog display on storage oscilloscopes from the three sensors will be required: one channel with bandwidth from 0 to 100 MHz and two channels with bandwidth from 0 to 10 MHz.

In addition, three simultaneous frequency distributions will be required: one frequency analyzer with an input frequency range from 0 to 100 MHz and two analyzers with a frequency range from 0 to 10 MHz.

5.35.7 Data

5.35.7.1 Scientific.- The scientific data will consist of the output of the frequency analyzer associated with each probe. Each analyzer will output 1000 8-bit words/second; therefore, the maximum data rate with all three probes operating simultaneously will be 24 kbps.

5.35.7.2 Housekeeping.- The housekeeping data will consist of approximately two to five analog signals to be Orbiter-digitized to 8-bit words, and each signal will be sampled once every second for a total bit rate of 40 kbps.

5.35.8 Development Status

5.35.8.1 Forerunner instruments.- Conceptually similar probes have flown on either satellites or rockets, but with lesser frequency and/or gain range than required for the present instruments.

5.35.8.2 Problems.- The anticipated problems with these instruments are discussed in the following subparagraphs.

5.35.8.2.1 Design and manufacturing: The primary problem to be encountered is the handling and transmission of the signal outputs of the probes from their point of location to the Orbiter cabin where analysis is to be performed. Large gain bandwidth products will be required with electronics of an advanced design.

5.35.8.2.2 Operational: If the RMS is utilized to extend the diagnostics outside the Orbiter bay, some method of determining their position and orientation must be devised.

5.36 LOW ENERGY ELECTRON BEAM EXPERIMENTS (LEEBEX) - INSTRUMENT 552

5.36.1 Objective

This instrument is to perform a quantitative investigation of linear and nonlinear wave-particle interactions in the ionospheric plasma by injecting a low energy (less than 10 eV) electron beam to artifically excite very low frequency (VLF) and high frequency (HF) plasma waves.

5.36.2 General Description

5.36.2.1 Location.- This instrument will be mounted on a boom.

5.36.2.2 Configuration.- The functional requirements document for the LEEBEX (Low Energy Electron Beam Experiments) describes two systems; the first will be a local-wave-phenomena receiver and electron-beam emitter. The first system will be composed of four subsystems: (1) an electron emitter; (2) dipole antenna sensors; (3) loop antenna sensors; and (4) telemetry. The second system will be used to measure the velocity distribution function of the injected beam and other plasma parameters. Its subsystems include: (1) dipole antennas similar to system 1; (2) loop antennas as used in system 1; (3) a magnetometer to measure local field strength (field direction has not been specified but will be required); (4) a particle analyzer (Faraday cup); and (5) two impedance probes, and of which will be positionable.

Both systems will be boom mounted, operating together in the same geomagnetic plane. In addition, system 1 must be electrically isolated from the Orbiter and have a self-contained power supply and telemetry system. Rechargeable batteries, which can be charged during standby periods, will be used as the power supply. The two 0.5 m diam. x 0.7 m long subsystems can be mounted on separate booms or on one boom with a "T" at the top to hold them at the separation distance. If separate booms are used, the Orbiter will have to be maneuvered to hold alignment with the magnetic field. By mounting the two systems on a platform at the end of one boom and controlling the platform through feedback from an orthogonal magnetometer, alignment with the changing field can be maintained. Control could be manual with a CRT display readout or could possibly be an automatic operation.

At Orbiter altitudes, the electrostatic plasma waves will interact resonantly with electrons having low energy (on the order of 10 eV or less). This will make it possible to effectively investigate wave-particle interaction.

This instrument will require the use of two booms or one boom on which the two systems can be deployed at the required separation distance of that has not yet been determined. System 1 must be isolated electrically from the Orbiter. Orbiter telemetry will be required for system 1. Not specified, but required will be a directional magnetometer located near system 1 for alignment of the two-part instrument with the geomagnetic field.

5.36.2.3 Specifications.- The specifications applicable to this instrument are delineated in the following subparagraphs.

5.36.2.3.1 Physical measurements: VLF will be measured with a wideband receiver and HF with a swept or stepped frequency receiver. System 2 will have a movable probe connected to an interferometer to measure wave-number spectra in addition to being able to measure frequency spectra.

5.36.2.3.2 Frequency and resolution: Electromagnetic energy will be received in the VLF range 0 to 30 kHz and in the HF range from 500 kHz to 20 MHz. The low energy electrons will be generated at about 10 eV and received from 0.1 to 10 eV. Some of the frequencies shown have not been specified, but were derived from other plasma accelerator experiments and proposed experiments.

5.36.2.3.3 Data collection rate: This instrument, as now configured, will be collecting analog data at a continuous rate. If digital conversion is used, the data rate can vary up to 30 kHz.

5.36.2.3.4 Power: System 1 will require 15 W of ± 15 V and 6 V power. System 2 power will average 1 W during operation with a maximum of 20 W. This increase will probably occur when moving the probe to various lengths.

5.36.2.3.5 Physical dimensions: The physical characteristics are as follows:

a. Systems 1 and 2 - 0.5 m diam x 0.7 m length (each will be a cylinder), 0.14 cu m (each stored)

b. Dipoles (two pairs on each system) - 10 m tip to tip

c. Loop antennas (two per system) - 0.3 m diam

The weight of systems 1 and 2 will be 10 kg each or 20 kg total (including dipole and loop antennas).

5.36.2.3.6 Other: System 1 will require use of Orbiter telemetry. Both systems will require a boom, 20- to 50-m long. If Orbiter maneuvering cannot meet the alignment requirements (with magnetic field lines), a steerable platform at the end of the 20- to 50-m boom will be required.

5.36.3 Operation

5.36.3.1 Pointing requirements.- This instrument will require ±2° accuracy in relation to the geomagnetic field.

5.36.3.2 Stabilization.- A rate of 0.1 deg/sec or less will probably be required. Orbital parameters will not be required, but good alignment of the Orbiter X-axis (if systems 1 and 2 are parallel to the X-axis) with the geomagnetic field will be required. Pointing and stabilization can become a problem, particularly in polar orbits where information of high interest to the scientists will occur. The magnetic field direction can change as rapidly as 5° per 1° rotation of the Orbiter about the earth.

5.36.3.3 Timeline.- Data takes will be about 30 minutes in duration. The instrument will be in a standby status the remainder of the time.

5.36.3.4 Constraints.- System 1, containing the electron-beam emitter, must be electrically isolated from the Orbiter for proper operation. EMI constraints have not been specified, but will be extreme with these types of antennas and wideband receivers.

5.36.4 Checkout and Test

The checkout and test requirements are yet to be analyzed and determined.

5.36.5 Controls

The following controls will be required as a minimum for this instrument:

a. Deployment

   1. System 1

   2. System 2

b. Loop Deployment

   1. System 1

   2. System 2

   3. Dipole length adjustment (four each for system 1)

   4. Dipole length adjustment (four each for system 2)

c. Power up

   1. System 1

   2. System 2

d. Telemetry - system 1

e. Retractable probe, length adjustment, system 2

f. Electron emitter, on/off

Joystick positioning of the instrument packages with the geomagnetic field will be required if the Orbiter cannot be aligned rapidly and accurately.

5.36.6 Displays

All control functions should have display feedback. In addition, if real-time data analysis can be done onboard, a display of wave-frequency spectra will be required. These data can assist in peak tuning of the adjustable antennas. If this is not possible, these data should be telemetered in real-time to the ground for analysis. CRT display of the instrument alignment with the geomagnetic meridian plane will be driven by feedback from orthogonal magnetometers mounted near the instruments.

5.36.7 Data

All data will be recorded in an analog format. The following table shows measurements to be taken and corresponding parameters.

Measurement	Bandwidth or frequency	Amplitude, volts	Number of channels
System 1			
VLF (freq.)	0 to 3×10^4	0 to 1	2[a]
HF	1×10^3	0 to 5	4
Beam current	2×10^2	0 to 5	2
Antenna	1×10^2	0 to 5	2
Housekeeping	1×10^2	0 to 5	1
System 2			
N_e, T_e, B_o	3×10^2	0 to 5	6
k	3×10^2	0 to 5	2
VLF (freq.)	0 to 3×10^4	0 to 1	2[a]
HF	1×10^3	0 to 5	4
Housekeeping	1×10^2	0 to 5	1

Note: [a]Wideband recording of frequencies indicated.

Housekeeping measurements were not specified in the functional requirements document. They have been added so that control functions will show feedback on the data. Also, battery voltages and package temperatures should be recorded.

5.36.8 Development status

5.36.8.1 Forerunner instruments.- An experiment similar to the LEEBEX, but not as detailed, was flown on a Japanese sounding rocket K-9M-41. This was reported in a paper by Matsumoto, Kimusa, and Obayashi, Ionosphere Research Laboratory, Kyoto University, October 1974. This reference was used as a basis for the frequencies shown in this instrument description.

5.36.8.2 Problems.- The problems anticipated with the development and operation of this instrument are discussed in the following subparagraphs.

5.36.8.2.1 Design and manufacturing: Even though prior instrumentation has been installed on sounding rockets and successful experiments accomplished, this instrument is more sophisticated than any that have been flown. Development will require additional effort.

The drawings accompanying the functional requirements document indicated grids on the Faraday cup, although no mention was made of them in the written documentation. Grids should be used and a modulated voltage imposed on one of them. The detector assembly now developed is a retarding potential analyzer, and calculations can be made from its data output to yield number of electrons (N_e) and temperature of electrons (T_e). Also, if the variable length impedance probe is still required, subsatelite mounting of system 2 should be considered before developing this instrument. Because of the long wavelengths involved, this will probably be the best method to the the separation required.

5.36.8.2.2 Operational: EMI environments were not specified in the requirements document but, because of the wide frequency ranges covered, could become a real problem. Magnetic field disturbance from the Orbiter will have to be well below ambient field conditions for system operation to be success. This also applies to E-fields. Alignment with the magnetic field is fairly critical within the indicated range, as the excited waves across field lines are at different frequencies and modes than those excited by injecting electrons along the field lines.

6.0 PAYLOAD ILLUSTRATIONS

This section contains four figures (6-1, 6-2, 6-3, and 6-4) which show the payload configuration for the magnetospherics and Plasmas experiments. Figure 6-1 shows the four basic pallets of the AMPS payload in the stowed configuration, and figure 6-2 shows the same AMPS payload in the deployed configuration. Figure 6-3 shows the Coherent Scatter Radar Instrument (410) in the stowed and deployed configuration. Figure 6-4 shows the chemical release module (Instrument 554) and booster rocket (Instrument 557) in the stowed configuration. This payload is an example of one which requires a majority of the payload bay space to be flown and is one of the special pallets referred to in table 2-I.

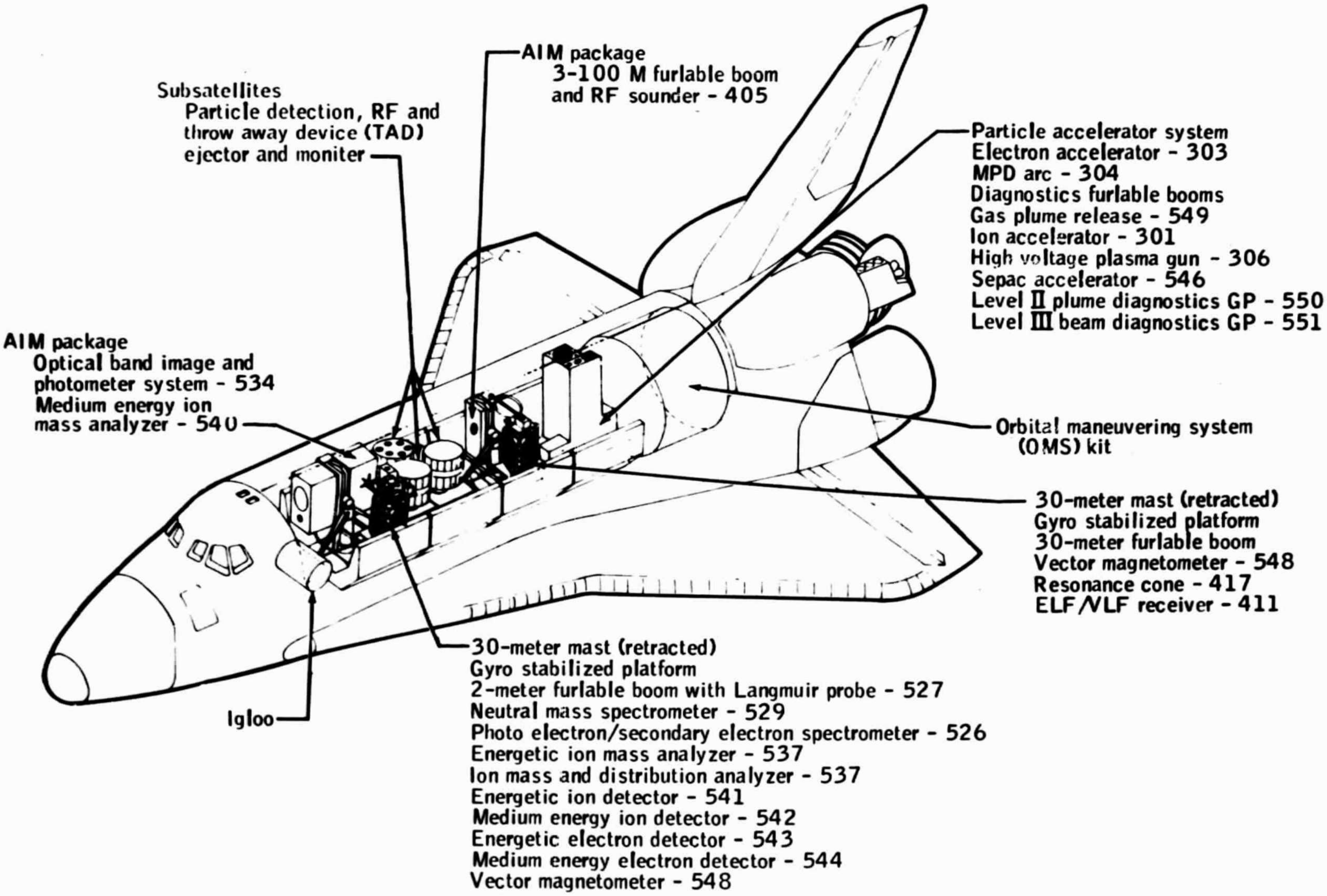

Figure 6-1.- Stowed configuration of magnetospheric and plasmas in space payload.

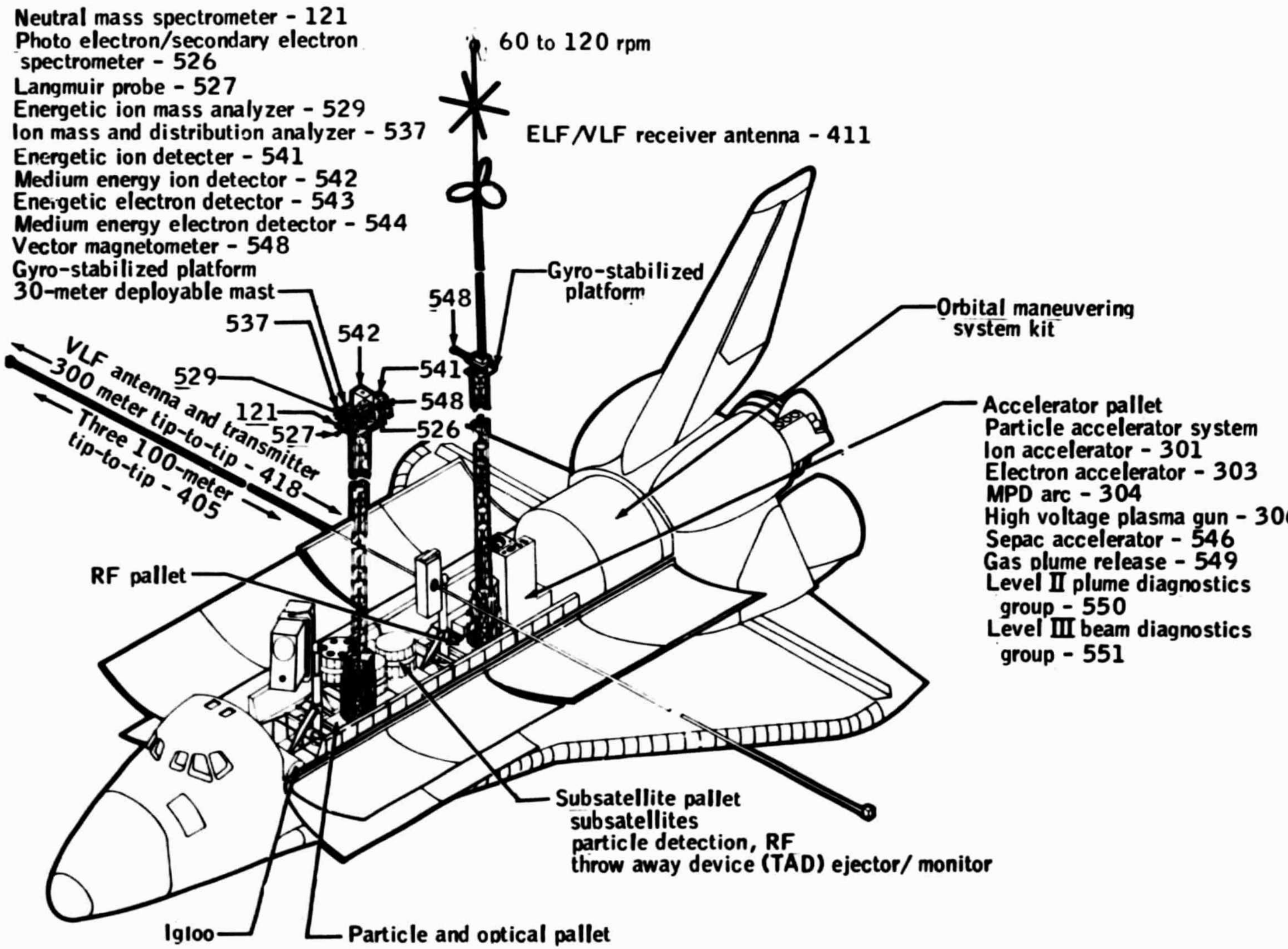

Figure 6-2.- Deployed configuration of magnetospheric and plasmas in space payload.

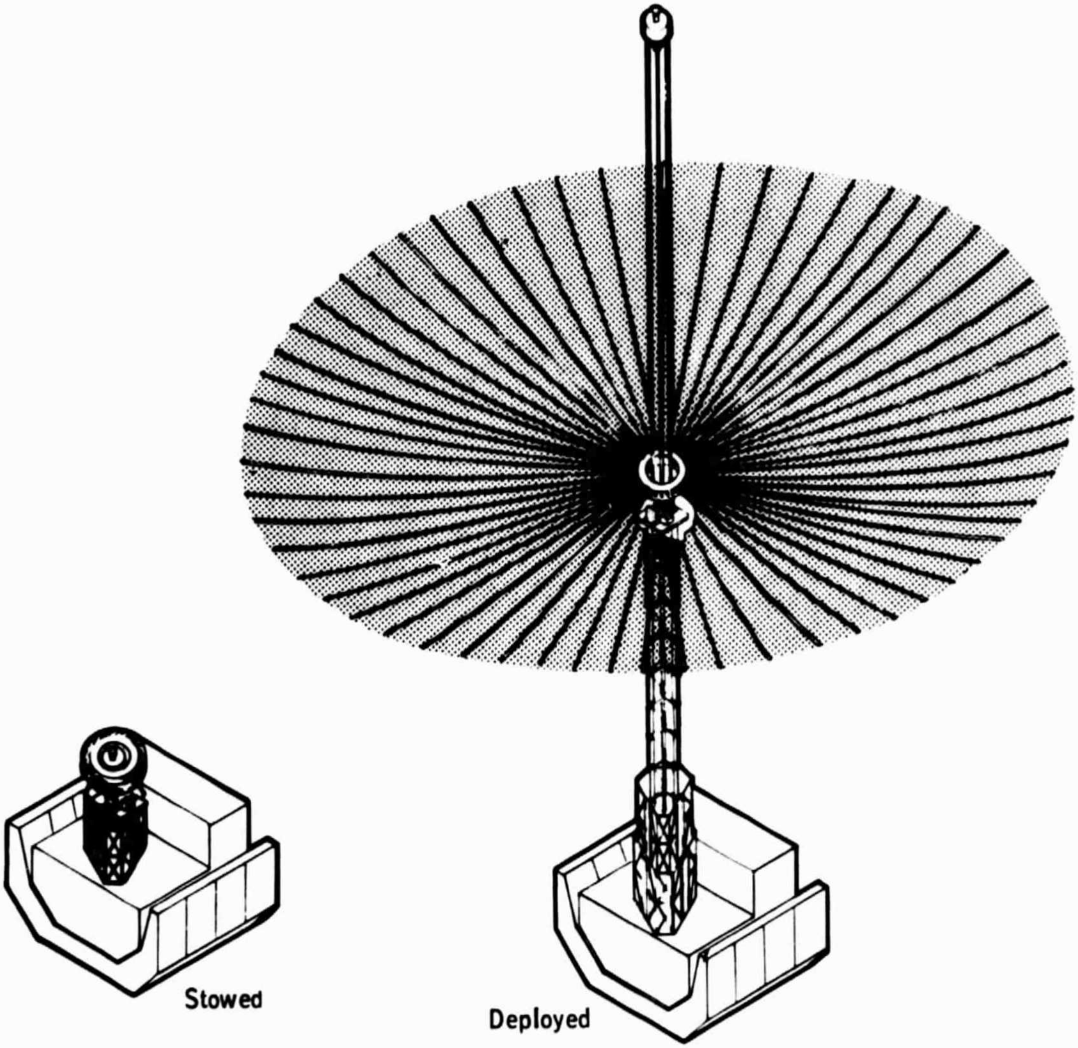

Figure 6-3.- Coherent scatter radar (Instrument 410) configuration.

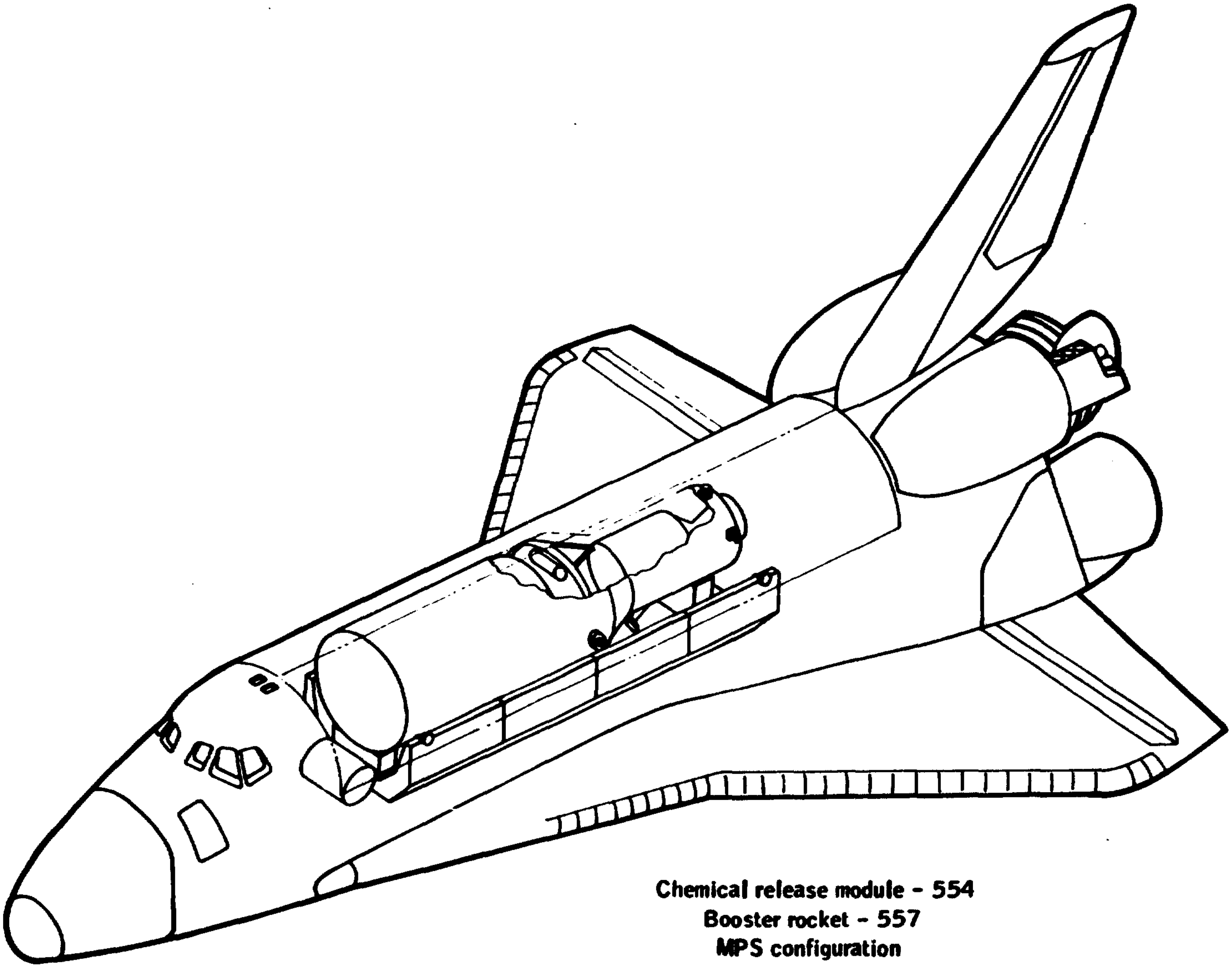

Figure 6-4.- Chemical release module and booster rocket configuration.

7.0 CONCLUSIONS

The following conclusions are made as a result of this study:

(a) The entire experiment requirements for the Atmospherics, Magnetospherics and Plasmas in Space cannot be accommodated in a single flight-configuration that would meet the existing scientific requirements. Since different experiments and disciplines have different orbital requirements, fixed pallets which can be changed between missions appears to be the most practical approach.

(b) The pallet-only mode is a viable approach to the Magnetospherics and Plasmas in Space experiment instruments as well as the Atmospherics experiment instruments presented in Volumes I through III of this report.

8.0 RECOMMENDATIONS

The following recommendations are made as a result of this study:

a. An evolutionary approach to instrument development should be used in that initially, the experiments would be accomplished using substitute instrumentation that had already been developed. More advanced instruments could then be developed for filling data gaps and refining original data. In addition, proposed instruments for AMPS are very costly and budgetary considerations will be a deciding factor in the acceptance of proposals. This factor alone can increase the value of using lower-cost off-the-shelf substitute instruments as budgetary considerations may otherwise rule out valuable developmental experiments.

b. Science requirements should be defined to the point that raw data can be processed on-board into a useful format. This would allow the majority of data processing to be done by the instruments, thus alleviating problems now forseen with tape recording, telemetry, and ground processing.

c. The relationship of AMPS to existing and future satellite programs must be determined. Effort should be made to integrate the programs where technically and economically feasible.

d. An experiment should be included to calibrate the solar satellite. Many proposed experiments require solar measurements for support and SOLRAD is a good candidate for this purpose.

e. Preflight and inflight calibration needs stronger emphasis. Calibration instrumentation should be developed as part of experiment instrument programs.

f. Availability and use of a payload computer with greater storage capacity should be investigated.

g. Data pre-processing by each instrument should be employed where possible to reduce the loading on the Orbiter communications and data subsystems.

APPENDIX A — ASF EXPERIMENTS DESCRIPTION

The information contained in this Appendix refines the Atmospheric Science Facility experiment descriptions found in Appendix A of Volume 2.

1.0 THE MEASUREMENT OF MINOR CONSTITUENT DISTRIBUTIONS IN THE ATMOSPHERE

1.1 THE BUDGET AND CHEMISTRY OF OZONE AND COMPOUNDS WHICH AFFECT ITS CONCENTRATION

This experiment is divided into three parts:

A. Budget and Chemistry of Chlorine Compouds

B. The Budget and Chemistry of Nitrogen Compounds

C. The Ozone Photochemistry Balance

1.1.1 Scientific Objectives

The scientific objectives are to determine the budget and chemistry of ozone and the factors which control its concentration. Chlorine and nitrogen compounds affect the concentration of ozone, therefore measurements of the concentration of compounds containing chlorine and nitrogen are made. Additional reasons for grouping these experiments together are their interrelation and the similarity of measuring techniques. Both chlorine and nitrogen exist in several compounds which change from one to the other by chemical reactions, thus it is desirable to measure all the nitrogen and chlorine compounds. The altitudes of interest are from 15 to 120 km. Solar radiation effects the concentration of O_3 directly, and indirectly by its affects upon the chlorine and nitrogen systems. Its spectral irradiance will be measured.

Specifically, it is desired to measure the concentrations of the following compounds and quantities:

Oxygen Allotropes	O, $O(^1D)$, $O(^1S)$, O_2, O_3
Chlorine Compounds	Cl, ClO, ClO_2HCl, CCl_xF_{4-x}, CH_xCl_{4-x}, x - 0 to 4
Other Halogen Compounds	SF_6, HF, Br, BrO
Nitrogen Oxides	$N(^4S)$, $N(^2D)$, NO, NO_2, NO_3, N_2O_5, HNO_3
Carbon Compounds	CO, CO_2, CH_4, H_2CO, CH_3OH
Hydrogen oxides	OH, H_2O, HO_2, H_2O_2, H, H_2
Solar irradiance	λ = 175 to 300 nanometers and possibly to 800
Temperature	—

Measurement of the concentrations simultaneously is desirable. However, known relationships exist between the above species so that the concentrations of some can be calculated.

1.1.2 Proposed Methods

Spectroscopic methods are used because of the difficulty of obtainint in situ measurements below 115 km. Spectroscopic methods include both downward looking and limb scanning.

Instrument 118, the Limb Scanning Infrared Radiometer, detects emitting compounds, and operates continuously during a mission while scanning the atmosphere from the horizon to an altitude of about 100 to 200 kilometers.

Instrument 129, the Infrared Interferometer and Instrument 126, the Cryogenically Cooled Interferometer Spectrometer, supplement instrument 118 by looking at the nadir and limb on alternate passes.

Instrument 213, the Laser Sounder, obtains the fluorescent spectrum in the visible and ultraviolet range. The instrument is pointed at the nadir and operates continuously at an estimated rate of one pulse per second. Instrument 124, the Fabry Perot Interferometer, obtains high resolution spectra from 200 nanometers up and alternately is used to detect the induced emission by Instrument 213. It looks at the limb

and nadir on alternate revolutions. It goes further into the ultraviolet range than the other instruments.

The temperature is measured from infrared spectra and UV (ultraviolet)-visible line shapes.

Instrument 532, the Gas Release Module, is used to measure reaction across sections involving the above chemical species.

The solar radiation is monitored spectrally in the UV and visible ranges with the solar subsatellite.

1.1.3 Typical Instruments

118 Limb Scanning Infrared Radiometer - NO, NO_2, N_2O, HNO_3, O_3, CH_4, Temperature

124 Fabry-Perot Interferometer - (TBD)

126 Far Infrared Spectrometer - ClO, CCl_x, F_{4-x}, NO, N_2O, NO_2, HNO_3, Temperature

129 Near Infrared Interferometer/Spectrometer - HCl, Cl_4, NO, CCl_4

213 LIDAR - Cl, NO, OH

532 Gas Release Module -

424 Microwave Limb Scanner -

1002 Pyrheliometer/Spectrophotometer -

— Solar Satellite

1.1.4 Orbit and Timeline Constraints

Low inclination orbits allow diurnal variations of species concentrations to be measured. High inclination orbits give global coverage and the opportunity to examine the effects of incoming particles at high latitudes. The altitude is not critical for most instruments, but the limb scanners will obtain better vertical resolution at low altitudes. However, the sensitivity of the laser is inversely proportional to the square of the range, thus as low an altitude as possible is desirable for laser operation. The experiment requires complete global mapping of the earth within the orbital track, ultimately covering the earth.

On a few of the revolutions, some of the infrared instruments look at the 4°K emission of space as a calibration check, 3 minutes at a time on the dark side of the earth.

1.1.5 Problems

The primary problems are associated with the elaborate and expensive optical instruments, some of which require further development. This includes the cryogenic technology, laser technology, and the infrared spectrometers with their specifications of high resolution. Also, the mathematical inversions necessary to obtain altitude information have problems.

1.2 CHEMICAL AND DIFFUSIVE EQUILIBRIUM IN THE MESOSPHERE AND THERMOSPHERE

1.2.1 Scientific Objectives

This experiment involves determining the composition and chemistry of the atmosphere at a higher altitude than for the previous experiment. Specific objectives are measurements of (a) hydrogen and hydrogen compounds, (b) helium and helium ions and, (c) oxygen ions; also, species which enable information about the above to be inferred. The temperature (from the band spectra) and the degree of excitation of the atmospheric species will also be measured. The species to be measured are H, H_2, He, O_2, O, O^+, N_2, N, N^+, OH, H_2O, NO, CO, CO^+, CO_2^+, and Ar.

1.2.2 Method

Because the altitude to be sensed is higher than the previous experiment, the atmosphere is thinner and there is more dissociation, which results in more atoms, other free radicals, ions, and inert gases being detected. The spectra involved are usually sensed in the ultraviolet and extreme ultraviolet rather than the infrared.

Emission spectra are taken of day airglow, night airglow, tropical airglow belts, polar aurorae, artificial aurorae, polar cap glows, the plasmasphere and exosphere with the Airglow Spectrograph and IV/VIS/NIR Spectrometer. Look directions include all angles depending upon the phenomena. The primary emphasis is on spectra below 140 nanometers, although data to 200 nanometers and possibly to 400 nanometers are important.

Stellar and solar occultation absorption measurements are made with the Occultation Spectrograph.

Measurements of solar ultraviolet and X-ray flux are made. Magnetic measurements are made both from the ASF subsatellite and the ground.

1.2.3 Typical Instruments

116	Airglow Spectrograph
122	UV/VIS/Near IR Spectrometer
124	Fabry-Perot Interferometer
534	Optical Band Imager and Photometer System
1002	Pyroheliometer/Spectrophotometer
1011	Ultraviolet Occultation Spectrograph
-	ASF Particle Detector Subsatellite
-	Solar Satellite

1.2.4 Orbital and Timeline Constraints

A polar orbit is preferred to obtain the most comprehensive coverage, particularly of the auroral zonesand polar cap regions, but ny important observations can be made with any orbit inclination. Any altitude above 200 km is acceptable. Comprehensive coverage of different times of the day, year, and solar cycle are desired. Maneuvers are necessary to permit pointing in any direction. During solar and selected stellar occultations, the Orbiter must be dedicated to Instrument 1011.

1.2.5 Problems

No difficult problems exist; however Instrument 1011 does require some development.

1.3 ABSOLUTE DENSITY AND THE VARIABILITY OF ATOMIC OXYGEN IN THE 80 TO 120 km REGION

1.3.1 Scientific Objectives

The atomic oxygen concentration in the 80- to 120-km range is variable and previous measurements were inconsistent. Knowledge of its concentration is useful in developing diffusion models. The objective is to measure the concentration of atomic oxygen by both remote sensing and in situ techniques.

1.3.2 Proposed Methods

Several methods should be used, each as a check on the others. In general, these methods are rather difficult and no best method exists.

The horizon is scanned at the 557.7-nanometer line of O with the Fabry-Perot Interferometer to give the altitude variation. To perform the inversion and obtain the altitude profile, the oxygen profile and temperature profile must be determined. The O_2 can be obtained from models or occultation. The temperature profile can be obtained from models or from the experiment described in paragraph 2.1.

The O profile is also obtained from stellar or solar occultation of the 130.4 line.

A direct method, requiring no mathematical inversion, is the measurement with lidar pointed at the nadir and operating at 130.4 nanometers. In addition, the laser can cause fluorescence of NO and its concentration can be determined, permitting a calculation of the O density.

A value of the concentration of O integrated with respect to altitude may be obtained by pointing Instrument 122 at the nadir.

In situ measurements are also desirable, but the minimum Orbiter altitude is about 200 km for a circular orbit and 150 km for the apogee of an eccentric orbit. A mass spectrometer on subsatellite o a 100 km tether vertically downward may be feasible.

It is desirable to cross-check the Orbiter measurements with data from rocket soundings.

Measurements of the solar flux in the spectral region of 120 to 250 nm should also be made. Radiation at those wavelengths cause dissociation of O_2.

1.3.3 Typical Instruments

122 UV/VIS/NIR Spectrometer

124 Fabry-Perot Interferometer

213 LIDAR

1011 Ultraviolet Occultation Spectrograph

- Mass Spectrometer on Tethered Subsatellite
- Solar Satellite

1.3.4 Orbit and Timeline Constraints

This experiment is applicable to all timelines and orbits and will require multiple flights for seasonal and geographic coverage. For the laser sounder, a low altitude is strongly preferred.

1.3.5 Problems

A laser operating at 130.4 nm will require considerable development and probably will not be available for the first AMPS missions. The Fabry-Perot interferometer, as specified, is difficult to make, but a simpler instrument would suffice for this experiment. The resolution of the ultraviolet occultation spectrograph may be insufficient.

1.4 D-REGION CHANGES AT MIDDLE LATITUDES DURING WINTER AND FOLLOWING GEOMAGNETIC STORMS

1.4.1 Scientific Objectives

In middle latitudes, the D-Region has an anomalously large absorption of radio waves in winter and associated with certain magnetic storms. The objective is to determine the relative importance of neutral atmosphere changes and particle precipitation effects, in particular, the height distribution of relevant minor constituents and mesophere temperature and also the fluxes of precipitated particles of appropriate (electrons >50 keV).

1.4.2 Proposed Methods

Nitric oxide, water vapor, hydrated ions, ozone and atomic oxygen abundance, and temperature will be measured by the spectrographic and laser probe techniques described in earlier experiments. Particle fluxes will be simultaneously measured for correlation purposes and to assess their import on regions of high precipitation, such as the South Atlantic anomaly. Infrared limb radiance profiles with Instruments 122 and 126 in the 1 to 16 micrometers range, as well as 64 micrometers for lines due to water, carbon dioxide, ozone, and atomic oxygen will be used to infer composition distribution. Resonance scattering of the visible solar radiation by hydrogen, nitrogen, and hydroxyl ions will be detected by Instruments 122 and 124 pointing near the nadir to provide data from which these concentrations will be inferred. Airglow emissions of atomic and molecular nitrogen should be seen under both sunlit and dark conditions. The airglow emissions result from excitation transfer, resonance scattering, fluorescence, chemical association, or photo-electron impact, either due to natural causes or to artificially induced forces excited by Instrument 213 pointing near the nadir. Particle data are obtained continuously from the subsatellite.

These observations should be made in conjunction with a ground-based balloon and rocket program of measurements directed toward the D-Region and stratospheric dynamics.

1.4.3 Instruments Required

122 - UV/VIS/NIR Spectrometer/Photometer

124 - Fabry-Perot Interferometer

126 - Far IR Spectrometer

129 - Near Infrared Interferometer/Spectrometer

213 - LIDAR

534 - OBIPS

- Particle Detector Subsatellite

1.4.4 Orbit and Timeline Constraints

Particle precipitation and seasonal anomalies are high latitude effects, making a near polar orbit highly desirable. Global coverage is a requirement. A low orbit is necessary to be as close to the D-Region as possible.

This experiment must be performed during times of no anomalies and at times when anomalies occur, as indicated by radio transmission effects.

1.4.5 Problems

The Orbiter and subsatellite cannot fly into the D-Region although it can probably come close enough so that in situ measurements correlate with measurements made in the D-Region. The tethered subsatellite requires development and might not be feasible.

1.5 METEORIC MATERIAL AND ITS INTERACTION WITH THE ATMOSPHERE

This consists of three independent experiments: (a) Cosmic Abundance of the Elements in Meteoric Material; (b) Meteor Production of Nitric Oxide; and, (c) Metallic Chemistry.

1.5.1 Scientific Objectives

A. The relative abundance of the elements in meteors indicates the relative abundance of elements in the solar system, especially for the heavier elements. The objective is to measure the concentration of the elements of meteoric origin in the atmosphere.

B. One hypothesis of the formation of NO in the atmosphere is that it is caused by thermal dissociation during meteor impacts and subsequent recombination. The objective is to test this hypothesis.

C. Metallic atoms are easily ionized by sunlight and are active in this role in the atmosphere. Meteors contribute to the metallic composition. To understand this role of metals, it is necessary to measure their concentration in the atmosphere and also the concentrations of neutrals and ions which react with them.

1.5.2 Proposed Methods

Measurements are performed during a meteor shower discussed in paragraph A and C and before and after test in paragraph B.

The LIDAR, pointed vertically downward, measures the concentration of NO and as many atom, ion, and metallic oxide species as possible. Generally the other instruments are pointed toward the horizon.

NO and metals are measured by the ultraviolet resonance scattering of sunlight observed near the terminator with the sun below the horion. As many constituents as possible are measured in emission including O ('S) at 557.7 nanometers and N(2D) at 520.0 nanometers. The UV/VIS/NIR Spectrometer, Near Infrared Spectrometer, and Cryogenic-cooled Limb Scanner sense O_2, N_2, O_3 and OH.

Occultation is used to detect some species.

Should the circumstances arse in which the Orbiter is in such a position that the travel of an appropriately sized meteor, something on the order of a gram, is close enough to be viewed for three seconds after the initial entry into a level of about 150 kilometers, this experiment could be attempted: The trail is tracked using Optical Bond Imager and Photometer System and radiometric measurements made with passive measurement of the NO by Instruments 124 and 126 pointed at the track location. If conditions should exist where the Orbiter passes nearly above a meteor track, active probing with the LIDAR will be attempted to observe induced emissions.

1.5.3 Typical Instruments

116 - Airglow Spectrograph

118 - Limb Scanning Infrared Radiometer

122 - UV/VIS/NIR Spectrometer

124 - Fabry-Perot Interferometer

126 - Far IR Spectrometer

129 - Near Infrared Interferometer/Spectrometer

213 - LIDAR

534 - Optical Band Imager and Photometer System

- Solar Satellite

1.5.4 Orbit and Timeline Constraints

Measurements are made within two days before a meteor shower, during the shower, and within two days after the shower. A low-inclination orbit has the best chance of success in a low, 200-kilometer orbit. The limb measurements and solar occultation are taken at twilight. The LIDAR measurements are obtained on moonless nights.

1.5.5 Problem Areas

The increase in concentration of NO and metals during a meteor shower is small and may be undetectable except in emission along a meteor trail. Problems may be that and LIDAR, except for detection of sodium and probably a few other elements in the visible and near ultraviolet, requires considerable development. Instruments 124, 126 and 129 also require development.

1.6 VIBRATIONALLY EXCITED OH (AND ITS EFFECTS ON ATMOSPHERIC CHEMISTRY)

1.6.1 Scientific Objectives

The OH vibrational population is measured for the following reasons:

A. The excited OH free radical excites homonuclear molecules (O_2 and N_2) whose energies are difficult to measure. (Near resonance transitions exist). To study the energy budget of the atmosphere, it is necessary to account for all the forms of energy resulting from solar radiation.

B. OH is formed in the vibrationally excited state. Therefore, Maxwell Boltzmann distributions of vibrational energy would not occur.

1.6.2 Proposed Methods

The primary method is fluorescence using a tuneable dye laser operating from 305 to 360 nanometers at target altitudes of 60 to 100 kilometers.

Within each vibrational band, it is necessary to determine the rotational distribution to evaluate the total band intensity. Hence, the rotational temperature distribution as a function of altitude is obtained simultaneously. One pulse is necessary for each rotational line. The sequence of wavelengths is computer controlled.

A second method is sensing emission from the limb in the spectral region 0.7 to 4.2 micrometers, but the lines are weak. Detection by ultraviolet fluorescence of solar radiation during twilight may also be feasible.

1.6.3 Typical Instruments

118 - Limb Scanning IR radiometer

124 - Fabry-Perot Interferometer

129 - Near Infrared Interferometer/Spectrometer

213 - LIDAR

1011 - Ultraviolet Occultation Spectrograph

1.6.4 Orbit and Timeline Constraints

To maximize the LIDAR sensitivity, it is desirable to have as low an orbital altitude as possible with any orbital inclination suitable. Global coverage is required.

1.6.5 Problem Areas

The pulses of the laser must be close enough together so that the spatial variation of OH excitation does not change the line strengths in a band during its measurement.

2.0 ENERGY BUDGET AND DYNAMICS

2.1 TEMPERATURE PROFILE FROM 50 TO 120 KILOMETERS

2.1.1 Scientific Objectives

The vertical temperature from 50 to 120 km is measured on a world-wide basis.

2.1.2 Proposed Methods

Laser sounding of the sodium provides neutral temperature measurements between 80 and 100 km. The line breadth is measured with the Fabry-Perot Interferometer. It is expected that the laser excitation of the OH radical will allow the extension of temperature measurements to the range 50 to 80 km.

Infrared spectrometry of the 2.7 and 15 micrometer bands of CO_2 enables the temperature to be measured below 60 km.

Broadening of the 557.7 nanometer line of O, as measured with the Fabry-Perot Interferometer, gives the temperature from 90 to 130 km on the night side, but the altitude of the originating atoms is not known accurately.

Profiling the limb with the FAR IR Spectrometer and Fabry-Perot Interferometer and measuring the line broadening may enable the temperature profile to be calculated.

2.1.3 Typical Instruments

118 - Limb Scanning IR Radiometer

124 - Fabry-Perot Interferometer

126 - Far IR Spectrometer

129 - Near Infrared Interferometer/Spectrometer

213 - LIDAR

424 - Microwave Limb Scanner

- Solar Satellite

2.1.4 Orbit and Timeline Constraints

A high-inclination orbit permits better global coverage. The altitude is as low as possible for minimum laser range. The laser is used only on a moonless night.

2.1.5 Problem Areas

All of the instruments require some development.

2.2 EDDY DIFFUSION COEFFICIENTS FROM THE DISTRIBUTION OF CONSTITUENTS

2.2.1 Scientific Objectives

In modeling the atmosphere, the models are very sensitive to the eddy diffusion coefficients which are poorly known. The concentrations of gases are not in local equilibrium because of eddy diffusion from above and below. Measurements of the vertical concentration profiles of various species results in data from which the eddy diffusion coefficients may be calculated.

2.2.2 Proposed Methods

Instruments 118 and 126, looking at the limb, measure O_3, CH_4, N_2O, NO, H_2O, and CO from the infrared emission. Instrument 1011 measures O, O_2, O_3, NO, CO, and CO_2 in occultation. Instrument 213 measures vertical profiles in the UV and visible and senses O, O_2, O_3, H_2O, NO, N_2O, CO, and CO_2. Instrument 124 measures the horizontal neutral wind.

2.2.3 Typical Instruments

118 - Limb Scanning IR Radiometer

124 - Fabry-Perot Interferometer

126 - Far IR Spectrometer

213 - LIDAR

424 - Microwave Limb Scanner

1011 - Ultraviolet Occultation Spectrograph

2.2.4 Orbit and Timeline Constraints

A low orbit is desired, especially for the laser. Orbits of both high and low inclinations are necessary to obtain global coverage.

2.2.5 Problem Areas

There are no difficult problems involved, but some development of the optical instruments is required.

2.3 HORIZONTAL WINDS IN THE MESOSPHERE AND THERMOSPHERE

2.3.1 Scientific Objective

Transport is extremely important in controlling the chemistry and energetics of the region above the mesopause. The objective is to measure the horizontal wind velocities.

2.3.2 Proposed Methods

Wind velocities are measured by the Doppler shift. For example, Instrument 124 is used to provide neutral wind data via the 557 nanometer and 630 nanometer airglow lines of atomic oxygen in the 90 to 120 km and 200 to 350 km altitude regions. In addition, Doppler shifts of resonant scattered solar radiation of various species should be detectable. Resonant scattered laser radiation from atmospheric sodium is detected at 590 nanometers. Absorption of scattered sunlight for O_2 should provide useful data.

2.3.3 Typical Instruments

124 - Fabry-Perot Interferometer

213 - LIDAR

- Particle Subsatellite (mass spectrometer and wind drift spectrometer)

408 - Tethered Subsatellite (mass spectrometer)

2.3.4 Orbit and Timeline Constraints

Horizontal Doppler measurements are made best when the altitude of the Orbiter is the same as that for which the measurement is desired. Data at all altitudes as well as global coverage are desired. An elliptical orbit to cover a wide range of altitudes with the perigee as low as possible appears best. Data on both high and low inclination orbits is desirable.

2.3.5 Problem Areas

Doppler measurements require very high resolution and the capability of sensing small shifts. If the specifications of the instruments can be met, there are no difficulties.

2.4 RELATIVE IMPORTANCE OF PARTICLE AND JOULE HEATING IN THE HIGH LATITUDE THERMOSPHERE

2.4.1 Scientific Objectives

There is heating in the ionosphere and magnetosphere at high latitudes due to joule heating and precipitating particles. Both intensify during magnetic storms. The dissipation of ionospheric electric currents depend upon ionization density, which is the magnitude of the convective electric field and ion collision frequency to gyromagnetic frequency ratio. The objective is to perform measurements which would permit the assessment of these two heating mechanisms.

2.4.2 Proposed Methods

Several parameters are monitored simultaneously. The electric fields and currents are measured using electric field antenna systems and vector magnetometers. They are combined on a TAD (throw-away device). At least three TADS not in a straight line and in a plane parallel to their velocity are used.

The ASF particle subsatellite is used to measure electron, ion, and neutral particle densities in situ. (The Langmuir Probe and Photoelectron Spectrometer measure the electron density. The High Energy Particle Detector detects electrons and protons in the range 25 keV to 10 meV. The neutral particle density and temperature are measured with the Mass Spectrometer and Neutral Gas Temperature sensors. In addition, the Cold Cathode Gauge measures the gas density. (No IFRD has been written nor

has any ID been assigned for the high energy particle detector or Cold Cathode Ion Gauge.)

In addition, optical measurements of the gas are made. The laser and Fabry-Perot Interferometer measure composition and temperature Doppler broadening.) The UV/VIS/NIR Spectrometer and Airglow Spectrograph measure the excitation of the gases.

2.4.3 Typical Instruments

116 - Airglow Spectrograph

122 - UV/VIS/NIR Spectrometer

124 - Fabry-Perot Spectrometer

213 - LIDAR

535 - Dc Electric Field

- Particle Detector Subsatellite (neutral and ion mass spectrometers and Langmuir Probe)

- Solar Satellite (UV measurements)

2.4.4 Orbits and Timeline Constraints

A polar orbit is necessary because most of the phenomena occur in the regions of the polar cap and auroral oval. Several missions are necessary to obtain different local times. Orbits less than 400 km are probably preferred. The Fabry-Perot will need to look in two orthogonal directions. Coordination with radar, optical, and magnetic measurements from the ground is necessary.

2.4.5 Problem Areas

Determining if all the necessary measurements are being made and the large number of simultaneous measurements are the most difficult areas.

2.5 ATMOSPHERIC TIDES AND GRAVITY WAVES

2.5.1 Scientific Objectives

Atmospheric tides and gravity waves are an important source of energy in the lower thermosphere above 90 km. As the waves increase in altitude, their amplitudes rise due to the decrease in density. They are also propagated and dissipated by eddy and molecular viscosity. The objective is to obtain a comprehensive picture of the source regions and propagation. This requires simultaneous and independent global measurements of the altitude profiles of neutral winds, temperature, and density in the mesosphere.

2.5.2 Proposed Methods

For altitudes from 20 to 60 km, the wind velocity is obtained by the Fabry-Perot interferometer sensing Doppler shifting and broadening of Fraunhofer lines in scattered Rayleigh sunlight. From 80 to 300 km, the interferometer measures neutral wind and temperature by Doppler broadening and wavelength displacements of the 557.7 nanometer 0 line, the 589 sodium doublet and possibly other suitable atomic line airglow emissions.

Infrared measurements of Doppler shift are made from 200 to 100 km by observing absorption lines in solar occultation and determining the velocity profile. Also the temperatures are measured from the rotational spectral distribution of the bands. The global wind distributions are computed from the spatial gradients of global temperature distributions. Below 80 km, measurements of density and composition are made in the IR.

Above 80 km, density and composition are measured by solar occultation and with the UV/VIS/NIR Spectrometer. From 80 to 100 km, measurements are made of wind velocity, temperature, density, and composition with the laser.

Solar and geomagnetic indices are monitored to separate disturbances originating below from those of solar origin. The best time to perform this experiment is when the solar and geomagnetic activity is minimum.

2.5.3 Typical Instruments

118 - Limb Scanning Infrared Radiometer

122 - UV/VIS/NIR Spectrometer

124 - Fabry-Perot Spectrometer

126 - Far IR Spectrometer

129 - Near Infrared Interferometer/Spectrometer

213 - LIDAR

534 - OBIPS

548 - Vector Magnetometers

1002 - Pyroheliometer Spectrometer

1011 - UV Occultation Spectrograph

— - Particle Subsatellite (mass spectrometer)

— - Solar Satellite

2.5.4 Orbital and Timeline Constraints

Orbits with inclination of 20 to 70 degrees are acceptable. The altitude is not critical, but 250 km with a circular orbit may be preferred.

2.5.5 Problem Areas

The Doppler and line broadening measurements require high resolution performance of the instruments.

2.6 IONOSPHERIC CURRENT SYSTEMS

2.6.1 Scientific Objectives

The high electrical conductivity of the lower thermosphere allows large ionospheric currents to flow. The driving forces are the charged particles of the solar wind and the electric fields caused by the dynamo

action of the global tidal winds and magnetospheric convection. These currents result in Joule heating and are involved in the coupling of the magnetosphere and ionosphere. Considerable energy is involved. The currents are most significant in the aurora oval and at the equator. They are especially strong during magnetic activity.

The objectives are to measure the currents, the quantities associated with them, such as electric fields and electron densities, and the quantities associated with the phenomena causing the currents.

This experiment overlaps the magnetospheric experiment "Measurement of Field-Aligned (Birkeland) Currents".

2.6.2 Proposed Methods

Winds are measured, as in the experiment discussed in paragraph 2.5. The Fabry-Perot measures Doppler displacements of O (557.7 nanometers) from 80 to 100 km, sodium (589 nanometers) from 80 to 120 km and probably other suitable airglow emissions. They are also measured by the Doppler shift of Fraunhofer lines in Rayleigh scattered sunlight and IR absorption lines and bands observed in occultation on the sun's disk.

The Fabry-Perot also measures the drift of ions as well as neutrals to the extent that their concentrations are high enough to be detected. Ion and electron densities and drifts are measured with the particle subsatellite and, if feasible, with the tethered mass spectrometer. Images of the aurora are obtained with OBIPS.

TAD's (throw-away devices) with magnetometers and trackers for orientation information may measure the current via the curl of the magnetic field. Three to six of the devices are necessary.

Electron densities are measured with radar from the ground. Magnetic changes are monitored throughout the globe.

2.6.3 Typical Instruments

118 - Limb Scanning Infrared Radiometer

124 - Fabry-Perot Interferometer

126 - Far IR Spectrometer

129 - Near Infrared Interferometer/Spectrometer

213 - LIDAR

534 - OBIPS

535 - D.C. Electric Fields

548 - Vector Magnetometers

— - Solar Satellite

— - Particle Subsatellite

555/548 - ESP

2.6.4 Orbital and Timeline Constraints

The experiment is carried out during a variety of geomagnetic conditions, seasons, and solar activity. Orbits with different inclinations are desirable. If the orbit is polar, a noon-midnight path is necessary. Observations of the limb must be made in directions at right angles to each other.

2.6.5 Problem Areas

The Doppler measurements require high resolution. If the high resolution optical instruments can meet specifications, there is no problem, but the specifications may be difficult to meet. Much of the data comes from subsatellites and TAD's. Such measurements are more expensive and less reliable than those made from the Orbiter.

2.7 PHYSICAL PROCESSES IN THE AURORAL ATMOSPHERE

2.7.1 Scientific Objectives

The objective is to investigate magnetosphere-ionsphere-mesosphere interactions through spectroscopic observations, especially narrow band imagery of auroral ultraviolet emissions shortward of 2000Å (extreme UV or EUV). Perhaps 60 percent of the incoming auroral particle energy is released in the form of X-ray and UV radiation between 1 and 200 nanometers. This radiation is highly ionizing and can modify the ionization of the atmosphere. Also, details of this radiation may reveal information about the interaction between the magnetosphere, ionosphere and neutral atmosphere. The primary emphasis is on the spectral region (60 to 120 nanometers) where the radiation is highly ionizing.

2.7.2 Proposed Methods

The auroral zone is mapped in the EUV by OBIPS. EUV channels are used on all of its sensors. Narrow filters to isolate band systems are employed. The filter wheel is rotated to obtain images in several different band systems. The focusing optics are wide angle to cover as much of the aurora zone as possible.

UV spectra are also obtained with the UV/VIS/NIR Spectrometer, Fabry-Perot Interferometer, and Airglow Spectrograph. These instruments, looking at the nadir, scan along a North-South line. The scan is advanced each orbit, giving a full image.

2.7.3 Typical Instruments

116 - Airglow Spectrograph

122 - UV/VIS/NIR Spectrometer

124 - Fabry-Perot Interferometer

534 - OBIPS, for example with interference filters at 121.6, 130.4, 135.6, 145.0 and 180 nm.

535 - D.C. Electric Fields

— - Particle Detector Subsatellite

— - Solar Satellite

2.7.4 Orbit and Timeline Constraints

A polar orbit is necessary to view the auroral zone. Also, a high altitude is necessary to view as much of the aurora zone as possible with the OBIPS TV.

2.7.5 Problem Areas

The primary problem is obtaining UV optics, namely the lens and/or mirror systems, narrow-band filters and TV sensors to operate below 180 nanometers, especially below 120 nanometers. Also, it is especially difficult doing this with a wide-angle system. These difficulties should not prevent performing the measurements, but probably compromises are necessary.

3.0 INFLUENCE OF SOLAR WEATHER ON CLIMATE

3.1 CORRELATION BETWEEN PARTICLE PRECIPITATION AND OZONE VARIABILITY

3.1.1 Scientific Objectives

Theoretically, solar proton fluxes creating polar-cap absorption events would lead to large production of NO as low as 25 km. At these levels, NO would be expected to catalytically destroy O_3. The variation in the concentration of O_3 is one of the most likely mechanisms for the solar wind affecting the weather. The objective is to determine the correlation between particle fluxes and concentrations of NO and O_3. This requires measurements not only of NO and O_3, but also NO_2, N_2O_5 and HNO_3.

3.1.2 Proposed Method

NO is detected by the LIDAR pointing vertically downward and operating at 215 nanometers. All the mentioned species are detected by the Limb Scanning Infrared Radiometer, the Far IR Spectrometer or the Near Infrared Interferometer/Spectrometer looking at the limb.

The ASF particle detector satellite and solar subsatellite monitor the particle and ultraviolet flux.

Later, during the data analysis, the correlation between O_3, NO, and particle fluxes will be determined.

3.1.3 Typical Instruments

118 - Limb Scanning Infrared Radiometer

126 - Far IR Spectrometer

129 - Near Infrared Interferometer/Spectrometer

213 - LIDAR

424 - Microwave Limb Scanner

— - Particle Subsatellite

— - Solar Satellite

3.1.4 Orbit and Timeline Constraints

A polar orbit is necessary. The altitude should be as low as possible, especially for the laser. This experiment overlaps Experiments 1b, 1c and 15 to a considerable extent. Experiment 15 is also performed in a polar orbit and should be performed at the same time to the extent feasible. Experiments 1b and 1c have preferred low-inclination orbits and this may limit the multiple use of the same data.

Data are taken before, during, and after an auroral storm or PCA (polar cap absorption). The best chance for success is during high solar activity or during the winter.

3.1.5 Problem Areas

The target for the laser is at a low altitude, requiring a maximum range and causing a low signal strength.

3.2 ANOMALOUS NEUTRAL COMPOSITION NEAR AURORA

3.2.1 Scientific Objectives

This experiment is similar to Experiment 14, except that the emphasis is on a higher altitude and additional chemical species are sensed.

The concentrations of certain minor constituents are enhanced during auroral activity to a much greater extent than would be expected and the energy associated with these changes is much greater than expected. These large increases in concentration and horizontal transport of constituents may be associated with the triggering mechanisms for meteorological phenomena. The primary objective is to measure the increases in concentration of these constituents and the particle flux which initiates the changes. Secondary objectives are the measurement of the horizontal transport of these constituents and other parameters such as electric and magnetic fields. Transport measurement is covered in Experiment 9.

3.2.2 Proposed Methods

This experiment complements Experiment 14 and should be performed on the same mission. Also, it is a part of Experiment 16 and other parts of Experiment 16 may be performed at the same time.

The concentration of NO is measured with the LIDAR at all detectable ranges from the Orbiter, but especially in the E region. It is expected that a pulse energy of 0.05 joule, a repetition rate of 2 per second, a receiving mirror 1.5 meters in diameter will yield height and latitude resolutions of 1 km and 1°, respectively, with a measurement accuracy of 10 percent.

OBIPS obtains images and photometric measurements of H at 486.1 nanometers, N_2^+ at 391.4 or 427.8 and O at 557.7 nanometers, which enable the ionizing flux to be calculated. It also images NO at 215 nanometers and OH at 306 nanometers to determine their distributions. One of the photometers is designed to sense the 1.27 micrometer band of O_2.

The ASF Particle Detection Subsatellite is required to measure electron and ion energies ranging from 1 keV to 40 keV. Magnetic measurements and radar measurements of the ionosphere should be made at the same time. Rocket flights to measure electron velocity distribution and densities of E and F regions are desirable.

3.2.3 Typical Instruments

116 - Airglow Spectrograph

122 - UV/VIS/NIR Spectrometer

124 - Fabry-Perot Interferometer

126 - Far IR Spectrometer

129 - Near Infrared Interferometer/Spectrometer

213 - LIDAR

424 - Microwave Limb Scanner

534 - OBIPS

535 - D.C. Electric Fields

548 - Vector Magnetometer

— - Solar Satellite

— - ASF Particle Detector Subsatellite

3.2.4 Orbit and Timeline Constraints

An orbit inclination of about 85° is necessary with an altitude of 200 km. Data are taken before, during, and after an auroral storm or polar cap absorption. The best chance for success is during high solar activity or in winter. The observations should be confined initially to night to minimize background radiation.

Experiment 14 has some objectives and procedures which are similar and they may be performed together. Most of this experiment also exists as part of Experiment 16 which has a very broad spectrum of measurements and it is highly desirable to perform some of Experiment 16 measurements at the same time.

3.2.5 Problem Areas

Of the important measurements, the most difficult to achieve are the laser measurements.

3.3 THE INFLUENCE OF SOLAR MAGNETOSPHERE VARIATIONS ON ANOMALOUS CLIMATOLOGICAL CONDITIONS

3.3.1 Scientific Objectives

Although numerous types of statistical correlations have been identified between variations in solar and magnetic parameters and in climatological parameters such as pressure, winds, rainfall, etc., experiments have yet to be performed to identify specific mechanisms which might be responsible for one or more of these types of tentative correlations. Owing to the relatively small amount of energy input thought to be available in the solar corpuscular component, most previous work in this area has led to the assumption that trigger mechanisms must be involved, leading to a subsequent magnification of the initial energetic disturbance through a dynamic or energetic response propagating across wider regions of the lower atmosphere.

A number of possible mechanisms exist for explaining the link between solar-magnetospheric and meteorological variations. Among these are: d) modification of ozone concentration triggered by energetic means, such as particle precipitation, X-rays or secondary radiation; b) modification of ozone concentration distribution triggered by dynamic mechanics, such as large scale redistribution of ozone or catalytic loss or production of ozone; and, c) modification of lower atmosphere temperature/pressure fields resulting from albedo changes linked with increased cirrus cloud coverage near the 300-millibar level initially produced by particle precipitation activity. The objective is to obtain data on atmospheric phenomena which may reveal this triggering mechanism.

3.3.2 Proposed Methods

Experiments 14 and 15 fulfill part of the objectives of this experiment and are performed on the same mission. This experiment involves measuring so many variables that it may be subdivided later into several experiments.

Measurements are performed before, during, and after a substorm. Because of the large numbers of measurements which can be made, the uncertainty of which are most important, and the real-time capability, it is expected that the choice of data and emphasis will be changed frequently during the mission in real-time depending upon the phenomena observed.

Measurements are divided into "upper atmosphere" (>150 km) "lower atmosphere" (<150 km) and ground-based measurements.

The upper atmosphere measurements include measurements of the electric and magnetic fields, energetic particles, ion composition and ion drifts, and neutral composition, drifts and energies.

Lower atmosphere measurements include chemical composition, trace constituents and contaminants. This part is like Experiment 1. Both nadir and limb measurements are made to separate spatial and temporal changes. Species measured include O_3, CO_2, H_2O, OH and NO_X. Temperature measurements (Experiment 7), wind measurements (Experiment 9) and airglow measurements are made. Airglow imagery is obtained with OBIPS.

Ground-based measurements include magnetic fields from which plasma convection and the interplanetary magnetic field are deduced. There is remote sensing, especially by LIDAR, of O_3 and contaminants.

3.3.3 Typical Instruments

Number	Name
116	- Airglow Spectrograph
118	- Limb Scanning Infrared Radiometer
122	- UV/VIS/NIR Spectrometer
124	- Fabry-Perot Interferometer
126	- Far IR Spectrometer
129	- Near Infrared Interferometer/Spectrometer
213	- LIDAR
534	- OBIPS
535/ 555	- Electric Field Measurement
548	- Vector Magnetometer
1011	- UV Occultation Spectrograph
424	- Microwave Limb Scanner
—	- Particle Detector Subsatellite
—	- Solar Satellite

3.3.4 Orbit and Timeline Constraints

A polar orbit is necessary with a day/night local time orbit with orbit to orbit continuity, i.e., no longitude gaps.

3.3.5 Problem Areas

Due to the uncertainty of what phenomena is most important, it is necessary to obtain a large amount of data to be correlated later. The large amount of data may cause timeline and data handling problems. More detailed statements of the methods are necessary. To simplify the acquisition of data, it may be desirable to split this experiment into several.

4.0 LABORATORY EXPERIMENTS IN BASIC AND MOLECULAR PROCESSES

4.1 BASIC ATOMIC AND MOLECULAR PROCESSES RELEVANT TO AERONOMY AND ASTROPHYSICS

4.1.1 Scientific Objectives

The objective of this experiment is the measurement of atomic and molecular parameters, the knowledge of which is necessary in modeling the atmosphere as they are presently unknown. These parameters include cross sections for excitation, ionization or dissociation by solar radiation and the same by electron collisions, radiative lifetimes and various reaction rates. The chemistry of metastable species and free radicals is little known. The freedom from wall collisions and low densities which slow down reaction rates enable phenomena to be studied in space which are difficult to detect in the laboratory.

4.1.2 Pr posed Methods

The gas release module has a reaction chamber in which the density is controlled. Solar radiation of all wavelengths enters the chamber causing photoionization, photodissociation, and excitation. Alternatively, a controlled quantity of gas is released into the space adjacent the vehicle and reactions occur with no walls. In the former case, spectroscopic instruments internal to the gas release module are used. In the latter case, the Laser Sounder, UV/VIS/NIR Spectrometer, and other remote sensing instruments of Orbiter are used.

Precise spectroscopic measurements are made of photodissociation, photoionization, excitation rates and branching ratios both from the ground state and long-lined excited state, integrated over the entire solar spectrum.

Electron impact cross sections of metastable species are measured using an electron accelerator. Metastable states of singly and doubly ionized species, which have not been investigated in the laboratory, can be studied. Artificial aurora, caused by electron bombardment of gases may be produced in the vicinity of Orbiter.

Recombination rates and products are difficult to measure in the laboratory because the high density results in very rapid recombination and deexcitation. These rates are measured in the artificial plasmas around the Orbiter. The amount of excitation energy of the product is important because it can effect subsequent phenomena. For example, in

the reaction $O_2^+ + e \rightarrow O^* + O$, a low excitation energy would mean a high kinetic energy which would cause an atom to escape from a weak gravitational field like Mars.

Chemical reactions of free radicals are studied in the plasma. Their concentration in laboratory systems has been so low or their lifetime so short that only recently using laser fluorescence has much data been obtained.

Evaporation processes from condensed matter, simulating, for example, interplanetary dust grains or a cometary nucleus, can be studied. A "dusty snowball" model of a comet may be tethered to the Orbiter. Laser fluorescence may be used to study the kinetics near the surface. (To simulate comet tails, it is necessary to be outside the earth's magnetic field.)

Calculations indicate that gas flow rates of 1 to 5 grams per second through nozzles of varying expansion ratios are sufficient for adequate measurement accuracies. A total quantity of 25 kg of gas is sufficient for determination of the specified constants at several varied compositional and density domains. For metastable species, more gas is necessary and an estimate is that 250 to 500 kg may be required for some experiments. Canister releases at a distance from Orbiter may be required for some experiments.

Two dimensional monochromatic imagery, as well as high resolution, is necessary for some experiments.

4.1.3 Suggested Instruments

Number	Name
116	Airglow Spectrograph
121	Neutral Mass Spectrometer
122	UV/VIS/NIR Spectrometer
124	Fabry-Perot Interferometer
129	Near Infrared Interferometer/Spectrometer
213	LIDAR
303	Electron Accelerator

304 - MPD Arc

532 - Gas Release Module

534 - OBIPS

548 - Vector Magnetometer

549 - Gas Plume Release (Level I Diagnostic)

550 - Level II Beam Diagnostics Group

— - Solar Satellite

4.1.4 Orbital and Timeline Constraints

This experiment should be performed at more than one orbital altitude. Low orbit inclinations will minimize natural particle inputs. Vehicle attitude with respect to the local magnetic field lines must be such that the accelerated electrons or ions do not impinge on the Orbiter vehicle during accelerator operation.

4.1.5 Problem Areas

The gas released may cause contamination of the associated optics.